Journal and Proceedings

OF

The Royal Society of Western Australia.

Vol. X.

1923-1924.

PRICE: Fifteen Shillings.

Perth:
By Authority: Fred. Wm. Simpson, Government Printer.

1924.

R 4722/24

CONTENTS.

PLATES.

TEXT FIGURES.

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LIST OF MEMBERS. *

(As at 1st July, 1924.)

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Maiden, J. H., I.S.O., F.R.S., F.L.S., Levenshulme, Turramurra Avenue, Turramurra, Sydney.
Pritzel, Dr. C., Str. 4, Hans Sachs, Berlin-Lichderfelde.

* Members are requested to notify the Hon. Secretary for Physical Science of any change of address.

LIST OF MEMBERS—*continued.*

Corresponding Members.

Alexander, W. B., M.A., Prickly Pear Laboratory, Sherwood, *via* Brisbane.
Cheel, Edwin, National Herbarium, Sydney.
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Clifton, A. R. C., Department of Agriculture, Perth.
Clubb, Wallace, B.A., Education Department, Perth.
Cohen, W. E., B.Sc., The University, Perth.
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LIST OF MEMBERS—*continued.*

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Garner, W. B., King's Park Road, Perth.
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Anderson, Miss Maggie, 253 St. George's Terrace.
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LIST OF MEMBERS—*continued.*

Associate Members—continued.

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1924.

Armstrong, Miss F., University, Perth.
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Hayward, Miss L., University, Perth.
Allsop, F. F., The University, Perth.
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Watson, E. M., The University, Perth.

PROCEEDINGS.

(*For period July* 10, 1923, *to July* 8, 1924.)

JULY 10, 1923. ANNUAL GENERAL MEETING. The President, Mr. E. de C. Clarke, in the chair.

Business : (a) The *Financial Statement* and *Annual Report* were received and adopted (Jour. Roy. Soc. W.A., Vol. IX., Part II., pp. 9–12).

(b) *Election of Council :* After receiving the report of the scrutineers the President announced the office-bearers for the year 1923–24 to be :

President— Professor A. D. Ross. *Vice-Presidents*— Dr. H. J. Lotz, Professor G. E. Nicholls. *Secretary for Natural Science*— Mr. W. E. Shelton. *Secretary for Physical Science*—Mr. R. D. Thompson. *Treasurer*—Miss Enid Allum. *Librarian*—Miss E. R. L. Reed. *Assistant Librarian*—Miss D. F. Milner. *Members of Council*—In addition to the above, the ex-presidents and Mrs. M. A. Shelton, Messrs. A. R. Galbraith, L. Glauert, L. W. Phillips, W. A. Saw.

Presidential Address : Mr. E. de C. Clarke—"The Pre-Cambrian System in Western Australia" (Jour. Roy. Soc. W.A., Vol. IX., Part II., p. 13).

AUGUST 14, 1923. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits : Miss E. R. L. Leed, *Utricularia* from Pinjarra, collected by Professor G. E. Nicholls.

Papers : Mr. W. H. Shields—"Sand bars on intermittent rivers—a new method of treatment" (Jour., Vol. X., p. 1). Mr. E. Cheel—"A new myrtaceous plant" (Jour., Vol. X., p. 5). Mr. L. Glauert "Notes on fossil plants from Mingenew and Irwin River" (Jour., Vol. X., p. 7).

SEPTEMBER 11, 1923. GENERAL MEETING. The President, Professor Ross, in the chair.

Exhibits : Mr. L. Glauert—Living specimens of a crustacean (*Upogebia bowerbanki*). Mr. H. Steedman—A species of *Polyporus*.

Papers : Mr. E. Ashby—"A new species and sub-species of *Acanthochiton*" (Jour., Vol. X., p. 13). Professor A. D. Ross—"A critical examination of the Einstein Eclipse tests" (Jour., Vol. X., p. 17). Professor G. E. Nicholls and Miss D. F. Milner—"A new genus of freshwater isopoda allied to *Phreatoicus*" (Jour., Vol. X., p. 23).

Address : An address on the history and work of the Australian National Research Council was delivered by Professor N. T. M. Wilsmore.

SEPTEMBER 20, 1923. SPECIAL GENERAL MEETING. The President, Professor Ross, in the chair.

Addresses were delivered by the following delegates returning from the Pan Pacific Congress :—Professor A. C. Haddon (Cambridge), Professor W. J. Perry (London), on ethnological problems of the Pacific, and by Dr. Sayers on miners' diseases.

OCTOBER 9, 1923. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits : Mr. L. Glauert—A fish-louse (*Ourozeuktes pyriformis*) infesting leather-jackets ; a sea-mouse (*Aphrodita australis*) ; a limpet (*Scutus anatinus*) ; living barnacles (*Scalpellum peroni*) ; an isopod (*Paridotea peroni*) ; an amphipod living in small fragments of *Cymadocea*.

Address : "The effect of wind-pressure on roofs" by Associate-Professor A. Tomlinson.

The President *announced* that the Council had appointed a committee composed of Professors A. D. Ross and G. E. Nicholls and Mr. A. C. Fox to co-operate with the British Medical Association and the Churches in an investigation of Spiritual Healing (for Interim Report see below).

NOVEMBER 13, 1923. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits : Dr. E. S. Simpson Precious opal from Stuart Range, Central South Australia ; cuprodescloizite from Gregory Range, East Pilbara ; caliche from Chili. Mr. L. Glauert—Polished turtles destined for British Empire Exhibition : a stuffed prize bull-dog.

Papers : Mr. W. E. Wood—"Increase of salt in soil and streams following the destruction of the native vegetation" (Jour., Vol. X., p. 35). Mr. L. Glauert—"Contributions to the Fauna of Western Australia, No. 5" (Jour., Vol. X., p. 59).

DECEMBER 11, 1923. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits : Dr. E. S. Simpson—Flame opal and tetrahedrite. Mr. T. Blatchford—Glaciated boulders of Carboniferous age from North-west, Western Australia (lat. 19° S.).

Papers : Dr. E. S. Simpson—"Goongarrite, a new mineral from Comet Vale, Western Australia" (Jour., Vol. X., p. 65).

Address: J. A. Wishaw—"Wireless Telegraphy and Telephony."

The President *announced* that the following committee had been appointed to investigate the increase of salinity in certain soils:—Professor Wilsmore, Dr. E. S. Simpson, Messrs. E. de C. Clarke, S. L. Kessell, and A. Montgomery (for Interim Report see below).

MARCH 11, 1924. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits: Mr. L. Glauert—Freshwater sponges. Mr. H. Steedman—Cones of pines and banksias.

Papers: Professor G. E. Nicholls—"*Phreatoicus lintoni*, a new species of freshwater isopod from South-Western Australia." (Jour., Vol. X., p. 91). Messrs. W. M. Carne and E. J. Limbourn—"The occurrence of certain natural cross-breds in oats and barley at the State Experimental Farm, Merredin, Western Australia." (Jour., Vol. X., p. 69). Mr. J. Clark—"Australian Formicidae." (Jour., Vol. X., p. 75).

APRIL 8, 1924. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Business: It was decided (a) that the Society award from time to time a Gold Medal for distinguished work in science connected with Western Australia, that the first medallist be Dr. W. J. Hancock, and that the Council draw up rules for the award of the medal; (b) that Rule No. 1 be amended to read: The general management of the affairs of the Society, together with the custody of its property, shall be vested in a Council, comprising a President, two Vice-Presidents, a Treasurer, a Secretary for Physical Science, a Secretary for Natural Science, a Librarian, an Assistant-Librarian, the retiring President, and eight other members.

Address: Major N. Brearley—"Aviation."

MAY 13, 1924. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Business: Rule 45 was adopted in the following form:—

45. A Gold Medal shall be awarded by the Council for distinguished work in science connected with Western Australia.

The method of making an award shall be as follows:—

(a) Awards shall be made by the Council only on a recommendation by a Medal Committee, and such recommendation shall require to be approved by not less than three-fourths of the members present at the Council meeting.

(b) The Medal Committee shall consist of five members of Council and shall be representative of various branches of science.

(c) Any recommendation by the Medal Committee for the award of the Medal must have the approval of at least four of the five members of the Committee and shall be accompanied by a statement setting forth the facts on which the recommendation is based.

(d) The Council shall appoint a Medal Committee (i) in the fourth year after any year in which an award has been made, (ii) in each alternate year thereafter until an award is made if an award has not been made as a result of the appointment of a Committee under the previous subsection, and (iii) at such times as the Council may consider it advisable to consider the question of an award to a particular individual, but no Committee shall be appointed under this subsection unless such action is approved by not less than three-fourths of the persons present at a Council meeting for which due notice of such proposed action has been given to each member.

(e) Any Medal Committee which is appointed under these rules shall report to the Council before the end of Society's year, and shall then lapse.

Exhibit : Mr. L. Glauert—An embryo kangaroo.

Paper : Professor G. E. Nicholls—"*Neoniphargus branchialis*, a new freshwater amphipod from South-Western Australia" (Jour. Vol. X., p. 105).

Address : Mr. L. Glauert—"Scorpions."

JUNE 10, 1924. GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Exhibits : Mr. L. Glauert—A living poisonous spider (*Latrodectes hasselti*), and a primitive Papuan fire-producing apparatus. Mr. W. M. Shelton—Fruting *Podocarpus drouyniana* (native plum or emu berry).

Paper : Mr. O. H. Sargent (communicated by Mr. L. Glauert) —"A systematic review of the germs *Hemiandra*."

Address : Mr. H. L. Sutton—"Rotation experiments at the Chapman and Merredin farms."

JUNE 28, 1924. ANNUAL CONVERSAZIONE. Held at the University, and commemorating the centenary of the birth of Lord Kelvin. A large gathering of members and friends assembled

to hear lecturettes bearing on different phases of Lord Kelvin's work and to inspect exhibits. Lecturettes were given by Professor A. D. Ross ("Gyroscopes"), Mrs. Ross ("Glacier motion"), Professor G. E. Nicholls ("The origin of life on the Earth"), Mr. E. de C. Clarke ("Age of the Earth"), Mr. A. A. Orton ("The first Atlantic cable"), and Mr. L. W. Phillips ("Solar Heat"). The exhibits comprised paintings of West Australian orchids by Mrs. Pelloe; paintings of butterflies by Miss Allum; fossils from the Irwin River by Mr. W. E. Cohen; sub-recent fossils from the Swan River coastal plan by Mr. J. L. Reath; art photographs by Mr. A. Knapp; wireless, high frequency, X-ray apparatus, and vacuum tubes by the Physics Department of the University; river algae and a rock python by Miss E. Stremple, Mr. K. Richardson, and the University Biology Department.

JULY 8, 1924. ANNUAL GENERAL MEETING. The President, Professor A. D. Ross, in the chair.

Business: (a) *The Financial Statement* and *Annual Repor* were received and adopted (see below).

(b) *Election of Council:* After receiving the report of the scrutineers, the President announced the office-bearers for the year 1924–1925 to be:

President—Professor A. D. Ross. *Vice-Presidents*—Professor G. E. Nicholls and Dr. E. S. Simpson. *Secretary for Physical Science*—Mr. R. D. Thompson. *Secretary for Natural Science*—Mr. W. E. Shelton. *Treasurer*—Miss Enid Allum. *Librarian*—Miss E. R. L. Reed. *Assistant Librarian*—Miss D. F. Milner. *Members of Council*—in addition to the above—Mrs. M. A. Shelton, Messrs. E. de C. Clarke (ex-President), F. E. Allum, W. M. Carne, W. Catton Grasby, A. Montgomery, A. Gibb Maitland, W. A. Saw.

Paper: Mr. C. A. Gardner—"Note on the so-called *Ericopsis formosus* Gardner" (Jour. Vol. X., p. 113).

Presidential Address: Professor A. D. Ross—"Theories regarding the æther" (Jour. Vol X., p. 115).

Presentation of Gold Medal: The Society's Gold Medal, awarded to Dr. W. J. Hancock in recognition of his work in radiography was presented to Mrs. Hancock (see below).

THE SOCIETY'S GOLD MEDAL.

THE FIRST MEDALLIST.

W. J. HANCOCK, D.Sc., M.INST.C.E., M.INST.E.E.

SOCIETY'S GOLD MEDAL—ITS INSTITUTION AND FIRST AWARD (To Dr. W. J. HANCOCK).

In presenting the Society's Medal at the Annual General Meeting on 8th July, 1924, the President (Professor Ross) said—

Scientific research is its own reward. There is nothing that can equal the pleasure of having achieved an important advance in human knowledge, and no incentive should be needed to stimulate scientific workers to prosecute research. Yet it is fitting that scientific associations should institute medals or other awards, not only as a recognition of duty nobly done, but also as an indication to the less scientific members of the community as to where honour is due. There is perhaps special need of such recognition being granted in Western Australia, for our isolation makes scientific work doubly difficult. Owing to the small population of our State, scientific men are called upon to prove themselves specialists not in one but in many branches of a wide subject, and, when research is undertaken, it has to be carried out without the help which comes from intercourse with others engaged in the same line of work and without the assistance obtainable in countries with extensive and up-to-date scientific libraries.

The institution of an award for distinguished scientific work in Western Australia has long been a desideratum. The opportunity came this year. The centenary of the birth of Lord Kelvin caused workers in every branch of physical and natural science to think of that genius whose activities had extended so widely and whose influence was yet a quickening factor throughout the world of research. As part of the commemoration of the Kelvin centenary, our Society decided upon the institution of a gold medal for meritorious research work, and so much did the idea appeal to members that the entire initial cost of preparing the die and the cost of the first award were voluntarily subscribed in special donations. The medal will normally be awarded at intervals of about four years, but every precaution has been taken to ensure a worthy standard in work in respect of which it is granted.

When your Council considered the first award, the proposal was carried unanimously to bestow it on Dr. William J. Hancock in recognition of his valuable work in radiography. Mr. Hancock had his early training in the University of Glasgow at a time when electrical science was making rapid advance, and in Lord Kelvin's physical laboratory he had experience in testing apparatus and plant when in process of development from the laboratory to the commercial type. Trained as an engineer, Mr. Hancock entered the Public Service in Western Australia in 1885 as an Imperial Service Officer under the Colonial Office, but in 1890 transferred to the State Service. From 1894 until his retirement a few years ago he held the important post of Government Electrical Engineer.

Immediately on the announcement in 1896 of the discovery of X-rays by Professor Röntgen, Mr. Hancock realised their importance in surgery, and took steps to procure the necessary apparatus for experimental work. This obtained, he carried out a number of preliminary tests and then offered his services as a radiographer in medical work in Western Australia. For a total period of 22 years he acted in an honorary capacity as radiographer to the Medical Department and to the Perth Hospital, attending to a large number of cases and placing his own apparatus at the disposal of these organisations. It is difficult to estimate the amount of work carried out during this long period, but the number of patients attended to was very large, and Mr. Hancock was busily employed each week on several evenings and late afternoons. Probably at least 30,000 X-ray tests were carried out in this way. During the war similar honorary service was carried out at the Base Hospital at Fremantle. In this connection it is to be remembered that Mr. Hancock was continually experimenting on improvements in the electrical apparatus and in devising new methods of locating the exact position of foreign objects in the body or of other features demanding special treatment. Several papers on these improvements in apparatus and methods were communicated by him to our own and to other scientific societies.

The Council have therefore felt that by his long-continued and meritorious work in connection with radiology in Western Australia, Dr. Hancock has thoroughly earned the right to be the first recipient of our Society's Gold Medal. He is a member of the Institution of Civil Engineers and of the Institution of Electrical Engineers, and during the past few months has been made an honorary member of the Institution of Engineers of Australia, while he has also been granted the honorary degree of Doctor of Science by the University of Western Australia. Unhappily Dr. Hancock has suffered the painful and serious harm which so many pioneer workers incurred through the use of X-rays. At present he is confined to his house by his illness, and I am certain that it is the sincere hope of every member of our Society that his health may improve and that we may again have the pleasure of welcoming him to our meetings. I am glad that Mrs. Hancock, who has passed through an anxious and trying time, is able to be with us to-night and to receive our medal to convey to her husband. Mrs. Hancock, on behalf of the Council and Members of the Royal Society of Western Australia, I have pleasure in handing you for your husband our Society's medal for his distinguished pioneer work in radiology in this State of Western Australia. It is fitting that this the first award of our medal, which bears on its obverse the portrait of Lord Kelvin, should go to a nephew of Professor James Thomson, the brother of Lord Kelvin. We wish Dr. Hancock a speedy restoration to health, and trust that even in his

illness it may be some consolation to him to know that that suffering is the price of helping very many of his fellowmen back to full health. Science is never so grand as when it benefits humanity, and your husband's work was of that quality. In placing his name at the head of the list of recipients of our medal we are setting a high standard for future awards.

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30th JUNE, 1924.

Ladies and Gentlemen,—

Your Council begs to submit the following report for the year ending 30th June, 1924:—

There are 253 members on the roll, of whom seven are honorary members, three corresponding members, 172 ordinary members, 63 associate members, and eight student members.

During the year 93 ordinary members and 29 associate members have been elected.

The Council records with regret the death of Mrs. Gavan Duffy, an associate member of the Society.

The following have resigned membership in the Society:— Miss Amy Alder, Mr. and Mrs. A. P. Amies, Mr. H. G. Beach, Mr. S. C. D. Brown, Mr. H. B. Curlewis, Mr. V. J. Matthews, Mr. McVicker-Smythe, Mr. Vanzetti, Mrs. and Miss Watson, and Mrs. Wilsmore.

There has been during the year a net increase of 93 per cent. in the ordinary membership, and of 58 per cent. in the associate membership of the Society. The Council desires to express its thanks to all those members who in response to the appeal made last year have been instrumental in securing new members of the Society.

The financial position having improved as a result of the increased membership, the Council has been just able to meet the cost of publications so far issued during the year, comprising the greater part of Volume X. (issued in pamphlet form) and the second half of Volume IX. There is, however, an urgent need of further expenditure on the library, more especially in binding copies of publications received in exchange, and in providing further accommodation. The Council, therefore, bearing in mind the financial assistance granted by every other State Government in Australia to its Royal Society, appointed a deputation to wait on the Premier with a view to securing an annual grant of £100. Although no definite reply has yet been received, the deputation met with an entirely favourable reception.

The new scheme of publication has been in force during the year, whereby papers have been printed and issued separately in pamphlet form immediately after being read. The cost of the 13 papers of Vol. X. so far issued is about £65. It is expected that the total cost of this Volume, which, when complete, will contain in addition to "Proceedings," list of members, etc., 15 papers occupying about 130 pages and including about 11 plates and 11 text figures, should be not more than £100. The total cost of Volume IX., published in two parts and containing 19 contributions of original matter, which occupied 166 pages and included six plates, 17 text figures, and two maps, was £97 7s. 2d.

It is likely, therefore, that the new method of publication will be more expensive than the old, but the Council considers that this increased cost is more than balanced by the advantages of quick publication, both to the Society and to authors. The Council hopes that more members, particularly those who cannot attend meetings, as they become more familiar with the operation of the scheme, will elect to receive papers as soon as they are published, and so keep in touch with the activities of the Society.

During the year, two committees have been appointed, one on "Spiritual Healing," and the other on "Salinity in Soils." Interim reports have been received from both committees, copies of which are attached.

On the recommendation of the Council, the Society has instituted a "Royal Society's Gold Medal," to be awarded for distinguished work in science in connection with Western Australia. The initial cost of procuring the die for the medal (and of the first award) has been met by voluntary subscriptions. It has been unanimously decided that the first award be made to Dr. W. J. Hancock, in recognition of his work in radiography.

There have been 13 meetings of the Council during the year, the attendance being as follows:—The President (Professor Ross) 10, Dr. Lotz nil, Professor Nicholls 8, Mr. Gibb Maitland 1, Mr. Montgomery 5, Mr. Sutton 7, Dr. Simpson 1, Mr. Allum 12, Mr. Clarke 10, Mrs. Shelton 13, Miss Allum 11, Miss Milner 6, Miss Reed 7, Mr. Galbraith 2, Mr. Glauert 7, Mr. Phillips 11, Mr. Saw 9, Secretary for Natural Science (Mr. Shelton) 13, Secretary for Physical Science (Mr. Thompson) 13.

There have been 10 general meetings of the Society during the year, and one special meeting held in September to welcome Pan-Pacific Science Congress Delegates.

The following is a list of papers read before the Society:—

Ashby, Edwin, "A new species and a new sub-species of *Acanthochiton*."

Brearley, Major N., "Aviation."

Carne, W. M., "The occurrence of certain natural crossbreds in oats and barley at the Merredin State Farm."

Cheel, Edwin, "A new W.A. myrtaceous plant."

Clark, J., "Australian Formicidae."

Glauert, L., "Notes on fossil plants from Mingenew and the Irwin River"; "Contributions to the Fauna of W.A., No. 5"; "Scorpions."

Nicholls, Prof. G. E., "A new species of Phreatoicus from South-Western Australia"; "A new amphipod."

Nicholls, Prof. G. E., and Milner, Miss D. F., "*Hyperoedesipus plumosus*—a new genus of isopod."

Ross, Prof. A. D., "A critical examination of the Einstein eclipse tests."

Sargent, O. H., "A systematic review of the genus *Hemiandra*."
Shields, W. H., "The treatment of bars on intermittent rivers."
Simpson, E. S., "Goongarrite, a new mineral from Comet Vale."
Sutton, G. L., "Rotation experiments at the Chapman and Merredin Farms."
Tomlinson, Assoc. Prof. A., "The effect of wind pressure on roofs."
Wishaw, J. A., "Wireless Telegraphy and Telephony."
Wood, W. E., "The increase of salt in soils following the destruction of the native vegetation."

The annual conversazione was held at the University on the evening of Saturday, July 28th. The centenary of the birth of Lord Kelvin fell on July 26th, and thus the commemoration of the life and work of this eminent scientist was made a special feature of this year's function. Exhibits were shown by the Physics Department of the University illustrating every phase of Kelvin's activities, while during the evening a series of lecturettes dealing with various aspects of Kelvin's scientific work was given by Professor and Mrs. Ross, Professor Nicholls, Mr. E. de C. Clarke, Mr. A. A. Orton, and Mr. L. W. Phillips. Various other exhibits were also shown by Miss Allum, Mrs. Pelloe, Mr. A. Knapp, Mr. W. E. Cohen, Mr. J. L. Reath, Mr. W. G. Hayman, Miss Rotenberg, Miss Stremple, and Mr. K. C. Richardson. The Council desires to express its thanks to all these members for their willing help.

A. D. ROSS,
President.

R. D. THOMPSON,
Joint Hon. Secretary

INTERIM REPORT OF SPECIAL COMMITTEE ON "SALINITY IN SOILS."

Committee Members: Professor Wilsmore (Chairman), Mr. E. de C. Clarke, Mr. S. L. Kessell, Mr. A. Montgomery, Mr. P. V. O'Brien, Dr. E. S. Simpson, Mr. G. L. Sutton, Mr. W. E. Wood (Convener).

Letters were sent to kindred bodies in the Eastern States asking for any assistance they could give. Replies have been received from most of them, but it appears that none of them have investigated similar happenings.

The Committee wrote to the Commonwealth Meteorologist asking him to assist in having rain water from well distributed rain-recording stations tested for its chlorine content. His reply was favourable, and he asked for our opinion regarding a list of stations submitted by him. After consideration it was decided to recommend the following, which would include one station in each of the areas which it is proposed to investigate:—

Fremantle, on the Indian Ocean.
Albany, on the Southern Ocean.
Cue, in the northern goldfields.
Coolgardie, in the eastern goldfields.
Mullewa, in the northern farming areas.
Merredin, in the eastern farming areas.
Wickepin, in the southern farming areas.
Mt. Barker, in the fruit growing and mixed farming areas.

It is hoped to have everything ready to start these tests on 1st July, 1924. The laboratory work will be done by the Railway Department at Midland Junction.

A circular letter was sent to 30 Road Boards asking them to distribute printed questionnaires, which the Committee supplied, to any farmers or others who had trouble with water becoming salt. The forms are being returned slowly, but enough are received now to show the wide distribution of the phenomenon and its importance.

(Signed) W. E. WOOD,
Convener.

30th May, 1924.

INTERIM REPORT OF SPECIAL COMMITTEE ON SPIRITUAL HEALING.

N.B.—The following report was received by the Council at the last meeting, June 4th, 1924. It was decided that discussion be postponed until the next meeting, and that in the meantime copies of the report be supplied to members of Council.

At a Meeting of the Royal Society of Western Australia, held on 11th September, 1923, it was decided, on the recommendation of the Council, to appoint a Special Committee, consisting of Professor A. D. Ross, Professor G. E. Nicholls, and Mr. A. C. Fox, to inquire into and report upon Spiritual Healing, particularly with a view to ascertaining :—

(i.) whether the methods of the healing missions were effective in ameliorating suffering due to ordinary disease ;

(ii) the types of case in which any such benefit was more probable or more pronounced ; and

(iii) the types of case, if any, in which definite harm might result.

Your Committee was fortunate in obtaining from the W.A. Branch of the British Medical Association a promise of every possible assistance in investigating cases. Three representatives of the Medical Association were appointed to discuss details with your Committee. The Anglican, Baptist, Congregational, Methodist, and Presbyterian Churches were approached with a view to obtaining their co-operation in securing patients for test—these being the denominations which, according to the press, were associated in the Hickson Mission services in the Perth Cathedral. The Anglican and Congregational Churches welcomed the proposed investigation and promised to give all assistance in securing subjects for the tests. Circulars, copies of which are attached to this report (N.B.—Attached to the original only) were drafted by our Committee and circulated to all ministers of the two co-operating Churches, and to members of the British Medical Association. It will be noted that the methods adopted were such as to involve no expense to patients, to obtain a clear statement of the patient's condition from his regular medical attendant and from a specialist in the particular disease, to ensure complete privacy regarding individual patients, and to avoid interfering with the element of faith which was recognised as an essential in the method of treatment.

Your Committee regrets that after a period of five months from the completion of the arrangements no patients have yet been obtained for the inquiry. So far as we can ascertain the employment of spiritual healing methods has been more or less in

abeyance in the two Churches who welcomed inquiry into the physical results of such treatment. Spiritual healing is, we believe, still employed by some representatives of other denominations. Your Committee desires to express its surprise and regret that these Churches should have thought fit to refuse co-operation in searching out the truth. We understand that some at least of these Churches consider that the physical cures effected by spiritual healing are minor in comparison with the moral and spiritual uplift of the patients, but we are led to believe that, with few exceptions, the patients present themselves on account of physical maladies.

At the April Meeting of Council permission was granted to your Committee to submit an interim report drawing attention to certain findings arrived at by Special Committees appointed by the Church of England. In October, 1910, a Conference of representatives of the Clerical and Medical Professions was held at the Chapter House, St. Paul's, to discuss "Spiritual" and "Faith" healing. A special Committee was appointed, and enlarged in October, 1911, to investigate spiritual healing, to consider how the dangers connected with such treatment by persons not medically qualified might best be guarded against, and to promote all legitimate co-operation between the professions. The Committee published a report in 1914, when the war interrupted further investigations. Under resolution 63 of the Lambeth Conference of 1920 of the Church of England, the Archbishop of Canterbury appointed a Committee to investigate spiritual healing, and its report was published early this year. The value of religious and mental influences as contributory to recovery are not questioned, but there is no suggestion of any supernatural cures. It is believed that the Divine Power is exercised in conformity with, and through the operation of natural laws. The physical results have not proved on investigation to be different from those of mental healing, or healing by suggestion, and no evidence has so far been found of any case of healing which cannot be paralleled by similar cures wrought by psychotherapy without religion and by instances of spontaneous healing which often occur even in the gravest cases in ordinary medical practice. At the same time it is strongly emphasised that the reinforcement of the faith, hope, courage, and strength of the sick by religious influences may often be the most potent form of suggestion, and where the religious influence is of a wise and reasonable kind, greater and more permanent results may be expected than from non-religious methods. The report of 1914 states that the Committee was forced to the conclusion that spiritual healing, like all treatment by suggestion, can be expected to be permanently effective only in cases of what are termed functional—as apart from organic—diseases. The alleged exceptions were so disputable that they could not be taken

into account. The Lambeth Committee, by their references to Psychotherapy, etc., appear to be of the same opinion. It has, of course, to be borne in mind that perhaps no sharply defined fundamental distinction can be drawn between organic and functional ailments. Great stress is laid on the importance of co-operation between clergymen and physicians. Ministrations appealing to the spiritual nature may greatly comfort and relieve people suffering from organic disease, but sufferers are warned against postponing medical treatment. The Lambeth Committee are of opinion that it is not the function of the Church to apply its means of restoration if no higher end is sought than the recovery of bodily health—the sick person must not look to the clergyman to do what it is the physician's or surgeon's duty to do, and *vice versa*. The only suggestion as to possible harmful effects of spiritual healing occurs in an expression of doubt as to the value of "services" of healing attended by large numbers of sick. It is noted that this involves questions of "mass psychology," and one gathers from this that while suggestion and feeling may be strengthened on such occasions, the accompanying excitement may be harmful to some patients.

The above opinions on spiritual healing are findings of committees composed of leading clergymen, doctors, and psychologists, and your Committee commends them to your careful attention. At the same time it feels that the subject calls for further investigation. The number of cases of organic disease which have been investigated is perhaps too small, and in some instances there was insufficient evidence as to the patient's condition before and after treatment. Your Committee trusts that opportunities may be obtained in Western Australia for arriving at more definite conclusions. There appears to be no doubt as to the beneficial results of spiritual healing methods in the case of many ailments. As to whether spiritual healing is purely a process of suggestion we have no certain evidence, and it was not a function of your Committee to inquire. If, however, spiritual healing is effective in the treatment of certain physical diseases, it appears most desirable that its power should be fully investigated.

Your Committee would express the hope that medical practitioners will accept the aid which apparently can be derived from religious influences, and that clergymen employing spiritual healing will not do so without relying on the advice of the patient's regular medical attendant.

In conclusion, your Committee has to express its thanks to the members of the W.A. Branch of the British Medical Association and to clergymen of the Anglican and Congregational Churches for their interest and promised help in investigating this subject.

A. D. ROSS.

G. E. NICHOLLS.

A. C. FOX.

STATEMENT OF RECEIPTS AND EXPENDITURE, YEAR 1923–24.

RECEIPTS.

	£ s. d.	£ s. d.
Balance on 1st July, 1923—		
Cash	3 2 6	
Bank	26 5 6	
		29 8 0
Subscriptions—		
1922 23	5 5 0	
1923–24	159 6 6	
1924–25	4 14 6	
Student Members	2 5 0	
		171 11 0
Fees for Reprints		7 17 1
Contributions to Medal Fund		33 18 6
Interest on Banking Account		2 10 3
		£245 4 10

EXPENDITURE.

	£ s. d.	£ s. d.
Government Printer—		
Vol. IX., Pt. 2	58 10 2	
Vol. X., Pts. 1 to 13	58 17 11	
Card Programmes, etc.	8 12 7	
		126 0 8
Fremantle Printery, Syllabuses, etc. ...		5 10 0
Art Photo. Engravers for Vol. X.		10 18 4
Wigg & Son, Index etc.		1 8 6
Museum Fees		14 14 0
Special Meeting on 20th Sept., 1923 ...		2 16 6
Petty Cash, Postage, etc. (including Launch Hire)		40 6 3
		201 14 3
Balance in hand on 30th June, 1924-		
Cash	3 3 6	
Bank (Medal Fund)	33 18 6	
(Ordinary Revenue) ... (£40 7s. 1d.)	6 8 7	
		43 10 7
		£245 4 10

Examined and found correct—
F. B. CREETH,
A. R. GALBRAITH, } Auditors.
7th July, 1924

ENID ALLUM,
Hon. Treasurer.

Sand Bars on Intermittent Rivers—a New Method of Treatment, by W. H. Shields, B.Sc., M.I.C.E., M.I.E.A.

(*Read* August 14, 1923. *Issued* September 11, 1923.)

In the south part of Western Australia most of the rain falls in three or four winter months, leaving eight or nine months of the year nearly rainless, with the result that the rivers become very feeble streams if not absolutely dry during the summer and, in many coastal areas, the sand driven by the prevailing currents or winds blocks the estuaries of rivers, and forms lakes cut off from the sea by sand dunes. Often clay and vegetable detritus accumulate in these lakes, making a valuable soil when the water is drained off.

The winter rains set the streams running, and if the estuary has been completely blocked the water spreads out and rises until it either filters through the sand or overtops the bar. In the latter case the water sweeps a gap in the bar that may remain open for months and sometimes is not closed in the succeeding dry season. When the mouth of the river is thus opened the land-water can escape at each low tide, and has never a higher dam than full tide (which seldom rises high during the summer) imposes, whereas the sand bar once formed may rise several feet above the usual tide mark.

Throughout the world many schemes have been devised to keep open rivers that are subject to the formation of bars of sand or shingle, the method employed depending on whether the river is navigable or not. At Fremantle the Swan River mouth is kept open for navigation by utilising the flushing effect of the lakes behind to produce sufficient scour through the narrowed entrance between the moles, to sweep away sand that may come round the ends.

Another type is the small river such as the one that discharges at Lockville near Wonnerup, about South Latitude 33° 30′ and East Longitude 115° 36′. Some years ago it was reported that the water in the inlet was drying up in the summer, with the result that the potato lands became too dry, and residents wanted the bar to be cut through to admit the sea water. The author recommended a culvert from the estuary to the sea under the bar to be carried out until its mouth was several feet above the level of the bottom. The shore did not seem to be advancing, and quite a small culvert would have admitted all the water necessary to keep the inlet supplied. However, this suggestion was not carried out.

At Grasmere, about South Latitude 35° and East Longitude 117° 40′, the conditions were rather different in that a considerable area of fertile cultivated land lay between high and low water, taking high water to mean the highest known tide, but above the ordinary summer tide level. The difference between high and low tide varies from about two feet in summer to a maximum of six feet in winter.

Quite large inlets exist at the head of a short outlet river of considerable size and depth, and into these inlets a number of large intermittent creeks discharge, besides a considerable stream of water perpetually running from the drains in the higher swamps.

The original settlers could dig drains that would keep the water-level in their swamps down, provided these drains could discharge at low tide. The sand bar, which is in this case wind-formed, however, held up the land waters, keeping the inlet too high for the drains from the lower swamps to discharge.

The Government put a row of flood-gates across the inland end of the outlet river, with the sill level, in round figures, about a foot above low water, expecting it to keep the bar open; later a portion of these gates was lowered until their sill was level with low water, spring tide. But still the bar formed, grew more formidable than ever, threatening to fill the outlet river right up to the flood-gates, and the advice of the author was sought.

Had it been possible to pour a fairly large and constant stream of water into the outlet river, between the flood-gates and the bar, there is no doubt that this water would have piled up in that confined area and breached the bar frequently, if it did not hold it continually open. The streams, however, do not run continuously and the drains, which do, carried during the summer far too little water for the purpose. It was also evident that the flap flood-gates which stopped any inward flow would stop all tidal scour up the inlet river, and thus the only available scour was that of the inland waters, which would have to remain impounded until sufficiently high to breach the bar either by overtopping it, or, if nearly at this height, by artificial excavation.

As constant a scour as possible had to be encouraged if the river, which was pretty deep, was to be kept open. The only flow, on a large scale, procurable for a great portion of the year came from the tides, so that it was clear from the first that the removal of the flood-gates was necessary.

The next question was how to maintain a constant opening in the bar so that land-water from the drains might escape at every low tide. During the summer a comparatively small culvert would take the drain waters, but it would require a large one to accommodate the early and late flows caused by sudden heavy showers, and a very big and expensive one to take all the winter flow.

In his experience in railway washaways the author had noticed that many of these took place without the bank being overtopped, apparently the eddies formed near the mouth of the culvert being sufficient to wash away the material forming the embankment until the culvert was left unsupported and water ran outside of it, enlarging the gap. Also on Indian rivers, the increased rush of water through the bridges, due to confinement of the flood-waters by the railway embankments on the river flats, carried away the silt in the river bottom to such a depth that the bridges frequently collapsed, so that it was found necessary to carry the piers down to great depths, if rock were not encountered. He has, therefore, advised that this downward-scouring property of rapidly flowing water be employed by constructing a culvert with sides and top that would allow of the sand being blown over it without blocking the waterway, but with no bottom. This culvert could be made large enough to maintain some scour in the river, and, having no bottom, whenever the current became rapid the stream would carry off the sand from the bottom, allowing the accumulation at the sides to be undermined and carried off, thus enlarging the gap in the bar and allowing the pent-up waters to rush through; the culvert being left standing on its supporting piles ready to function again the next time the drifting wind-blown sands tried to close the river mouth.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

A New Myrtaceous Plant, by **E. Cheel**, National Herbarium, Sydney. *Communicated by* W. M. Carne.

(*Read* August 14, 1923. *Issued* September 11, 1923.)

Baeckea minutifolia, sp. nov.

Frutex erectus ad 1·5 m. altus, ramis sub-confertis virgatis tenuibus. Foliis minutissimis ad $1\frac{1}{2}$ mm. longis, 1 mm. latis vel minoribus, oppositis, decussatis, oblongis vel oblongo-obovatis, turgidis vix angulatis. Bracteis in foliaribus axillis basi pedicellarum. Floribus solitariis in superioribus foliaribus axillis. Petalis sub-orbicularis 2-$2\frac{1}{2}$ mm. diam., obscuro-unguiculatis. Calycis tubo basi-attenuato. Staminibus 10, quinque brevibus, oppositis sepalis, quinque duplo longioribus oppositis petalis. Stylo ad 2 mm. longo, stigmate minutissimo capitato.

Plant usually growing into an upright shrub, up to 5 feet high, the branches slender and more or less virgate. Leaves very small, opposite and more or less decussate, oblong or oblong ovate, somewhat appressed, sessile, turgid, and slightly angular. Bracts small, at the base of the pedicels in the axils of the leaves, and somewhat resembling the leaves. *Flowers* of a pinkish colour, usually terminating the branchlets in the axils of the leaves, on distinct pedicels about 2 or 3 mm. long. Petals 5, orbicular or sub-orbicular, about $2\frac{1}{2}$ mm. diameter, obscurely clawed. Sepals ovate, acute, 1 mm. long, tinged with red at the apex. Stamens 10, five short opposite the sepals, and five about twice as long again, opposite the petals. Anthers sub-globose with two parallel longitudinal cells. Style 2 mm. long, stigma minutely capitate. Calyx-tube smooth, attenuated at the base on pedicel about 2 or 3 mm. long. Fruit apparently 3-celled, but ripe capsules not seen.

Habitat. Westonia, Western Australia. Collected by Mr. F. M. C. Schock in April 1918.

It has affinities with *B. crassifolia* and *B. Maidenii*, but differs from both in the branches and branchlets being less intricate or divaricate and in the flowers being much larger.

Type in the National Herbarium, Sydney, New South Wales.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

Notes on Fossil Plants from Mingenew and Irwin River, by L. Glauert, F.G.S. Communicated by permission of the Trustees of the Western Australian Museum.

(*Read* August 14, 1923. *Issued* September 18, 1923.)

Plant remains from the Jurassic strata near Mingenew were described by Dr. E. A. Newell Arber in 1910. Although the presence of a Permo-Carboniferous flora at Irwin River does not appear to have been recorded up to the present time, Mr. E. de C. Clarke informs me that Sir Edgeworth David obtained several specimens of *Glossopteris* during his visit in September 1921.

The specimens described below were obtained by a party of University students under the leadership of Mr. Clarke in May 1923.

JURASSIC PLANTS FROM OUTCROP OF FERRUGINOUS SANDSTONE ON SIDE OF MINGENEW-MULLEWA ROAD THREE MILES N. OF MINGENEW.

Otozamites feistmanteli Zigno 1881.

A number of specimens belonging to this species are in the collection, amongst them being two fine fragments of fronds about 130 mm. in length.

Nos. **G3778** and **G3813** are well preserved, enabling the venation to be seen most distinctly, and exhibiting the outline of many of the pinnules as well as the auriculate upper edge.

The pinnules are straight with a bluntly rounded apex, slightly imbricate, attached to the upper side of the rachis by a broad base with an auriculate upper edge.

There is a certain amount of variation in the shape and size of the pinnules; the length ranging from 8 mm. (**G3815**) to 20 mm. (**G3778** and **G3814**), and the width from 5 to 6 mm.; also in the longer pinnules the tip is less bluntly rounded than in the shorter ones. The veins, which are numerous and branching, radiate from the point of attachment, where they number from 10 to 12, and are obliquely cut off when they reach the margin. Measurements taken at random showed that about 20 veins are present in 5 mm.

The remains from this locality identified by Arber are not available for comparison, but there is every reason to believe that specimens **G3777**, **G3778**, **G3813**, **G3814** and **G3815** fall within the

limits of variation referred to by Arber (l.c. p. 26). At the same time it must be pointed out that the plants do not agree with Dr. Walkom's description of *Otozamites feistmanteli* from the Walloon Series of Queensland, which has the pinnules 12 mm. long, 4 mm. wide and the veins "divergent and dichotomous, being about 6 or 8 in number at the base and up to 12 in the widest part." Nor can they be assigned to Walkom's *Otozamites cf. mandelslohi* Kurr, which is defined "Frond linear, narrow, with a breadth of about 1·5 cm. The pinnae are rather orbicular, 8 to 9 mm. long and 7 mm. wide, with an obtusely rounded apex; they overlap slightly and are auriculate at their upper margin; they are attached to the upper surface of the rachis, the veins are numerous, fine, divergent and dichotomous, there being about 15 to 20 in a space of 5 mm."

Specimen **G3777a**, from near the apex of a frond, is similar to the others in most respects but differs in having all the pinnules slightly falcate. The apical pinnules are shorter and narrower than the basal ones but show the same amount of imbrication.

Pagiophyllum sp.

Specimen **G3779** consists of a portion of a twig which seems to be identical with the *Pagiophyllum sp.* of Arber's paper (op. cit. p. 27).

Permo-Carboniferous Plants from Carbonaceous Shale underlying the lowest Coal Seam in the North Branch of the Upper Irwin River.

? **Phyllotheca** sp.

Specimen **G3812** contains various plant remains including a piece of stem which may be *Phyllotheca sp.* or *Schizoneura sp.*, *Glossopteris browniana* and a number of indeterminate fragments.

Specimen **G3811** is covered on one side with *Glossopteris browniana* Brong. and numerous ribbed leaflets which may belong to species of *Phyllotheca.*

Sphenopteris lobifolia Morris 1845.

Specimen **G3810** consists of a portion of a frond, probably subapical, with one complete and six incomplete pinnae. The complete pinna is attached to a fragment of the rachis which is so imperfect that it is impossible to distinguish its wings; it does, however, show indications of the presence of a sub-opposite pinna. The pinnules are decurrent, roughly oval, and have a lobed margin. Their shape and venation very closely resemble the *Sphenopteris*

lobifolia figured by Arber in the Glossopteris Flora (British Museum) on Plate V., figure 2. The species was first collected in the "Newcastle Coal Mines," New South Wales (type locality) and has subsequently been obtained in the "Upper Coal Measures of Newcastle" (Feistmantel), Port Stephens and Mulubimba in New South Wales, and from the Upper and Lower Bowen Series of Queensland (Walkom). It is now recorded from the Permo-Carboniferous Beds of Western Australia for the first time.

Glossopteris browniana Brongniart 1828.

Specimen **G3804**, a small incomplete frond, with a well marked midrib, which appears to persist to the apex, is assigned to this species. At its widest part it measures 18 mm.; its length is 54 mm.

Specimen **G3806** contains three imperfect, elongate fronds with meshes which are short, broad and polygonal close to the midrib where they form one or two series before sweeping round obliquely to divide into the narrow polygonal meshes which occupy the greater part of the lamina. These three fragments I consider to be young fronds of this species.

Specimens **G3811** and **G3812** contain fragmentary fronds of this species associated with other plant remains.

Glossopteris indica Schimper 1869.

Specimen **G3805** is considered to belong to this species, the midrib is well defined and the nervure very distinct up to the arched margin for approximately two-thirds of the right side.

Glossopteris ampla Dana 1849.

Specimen **G3809** consists of a fragment of a very large frond 83 mm. long and 70 mm. wide, too imperfect to show anything beyond the midrib and the veins of the lamina, and indicating that the perfect frond was at least 110 mm. across. The median rib is strong but so imperfect that it is impossible to determine the structure; the nerves are parallel and more widely separated than in the specimens of *G. browniana*, *G. indica* and *G. angustifolia* being from ·5 to 1·0 mm. apart; their emergence is not visible but they are soon arranged in a direction almost at right angles to the median nerve, so that the change of direction must take place very close to the midrib. The nerves may be simple or they may divide once, twice or three times in a distance of 50 mm., and in a few places they seem to anastomose. This fossil by its large size and its style of venation differs from all the described and figured species of Australian Glossopterids, though it seems to be most closely approached by Dana's *Glossopteris ampla* which is

described by Arber (op. cit., p. 79): "Frond usually large, broadly oval, apex obtuse or emarginate; midrib stout, especially in the lower portion of the frond, but not persisting quite to the apex. Lateral nerves arched at midrib, forming one or two series of comparatively broad and short meshes, and then subdividing into a number of close, almost parallel veins, often very oblique, forming extremely narrow elongated meshes."

Walkom remarks concerning this species that it "is fairly easily distinguished from *G. indica,* the only species which approaches it at all closely, by the character of the network and the general appearance of the secondary venation. The meshes close to the midrib are short and broad, and in marked contrast to those further away, which are long and narrow. The secondary veins are generally straight, sometimes with a tendency to curve slightly upwards near the margin." And further, "the larger fronds examined . . . . are obviously more than 20 cm. long and 8 cm. wide and have an obtuse apex. The midrib is strong, up to 4 mm. wide, with a number of longitudinal striations. The meshes formed by the secondary veins are short and broad for a few rows along the midrib, but further out they become very long and narrow, the veins being sub-parallel. In the lower and central portions of the frond, the secondary veins are practically at right angles to the midrib (75°-90°)."

Feistmantel's *Glossopteris taeniopteroides,* regarded by Arber and others as a synonym of *G. indica,* which should also be taken into consideration, is rather narrower and has a more acute venation, the meshes of which are "larger on the borders of the midrib, contracting towards the margin" (Arber, op. cit., p. 66). The Irwin River frond differs from these in the absence of broad, short meshes near the midrib and the veins being straight, not showing a tendency to curve upwards near the margin.

? **Gangamopteris** sp.

Specimen **G3807**, a fragment of a leaf without any trace of midrib and with the veins dividing by dichotomy and anastomosing to form a network is hesitatingly determined as belonging to this genus.

? **Noeggerathiopsis** sp.

Specimen **G3808**, another fragment showing no trace of midrib, with the veins almost parallel dividing but not anastomosing to form a mesh, is considered to belong to some species of this genus.

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By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

A New Species and Sub-Species of Acanthochiton by Edwin Ashby, F.L.S. *Communicated by* L. Glauert.

(*Read* September 11, 1923. *Issued* October 16, 1923.)

Acanthochiton (Notoplax) spongialis n.sp. Plate I.

Introduction.—We are indebted to Mr. W. L. May of Tasmania for the discovery of the new and interesting form of *Acanthochiton* hereafter described. Altogether he dredged four specimens in 9–10 fathoms in the D'Entrecasteaux Channel. Southern Tasmania; one of these he generously gave to me as a deep water form of *A. speciosus* H.Ad., but on examining it under a strong lens one at once noticed that its girdle spicules were very different from those of that species.

Both Mr. May and myself thought that its distinctive characters might be due to senility and the depth at which it occurs, but the recent discovery by Mr. Glauert of a juvenile specimen with similar spicules on the girdle establishes the fact that this feature is not due to senility. Mr. May has been good enough to place at my disposal all his specimens, and he fully concurs with me in considering the form under review a new species.

General appearance.—Having a great width of girdle clothed with minute, slender spicules, valves small, shield-shaped with smooth, narrow and beaked dorsal areas. Colour buffish brown.

Anterior valve.—Decorated with flat, rounded to oval, squamose granules, showing five raised ribs which are defined and surmounted with larger and more elongate but otherwise similar granules to the rest of the valve.

Posterior valve.—Mucro post-median, slope behind mucro fairly steep, ray ribs absent or ill-defined, dorsal area smooth and narrow, rest of valve decorated with flat, slightly concave squamose granules, which become larger and more elongate laterally.

Median valves.—Dorsal area narrow, beaked, smooth except for slight transverse growth grooves and slightly granulose and pinnatifid in the juvenile portion. Other areas clothed with squamose granules, which are flat to concave, oval, arranged in somewhat irregular, longitudinal to radiating rows; these granules become more elongate laterally. There is present a shallow diagonal rib surmounted and defined by slightly larger and more elongate squamose granules.

Girdle.—The girdle is very broad, occupying five times as much space as the valves in the dry specimen and of course very much more in the living. The girdle is densely clothed with minute very slender spicules, which give to it a felted appearance.

The girdle encroaches between the valves and separates them from one another.

Measurements.—The type measures 38 x 18 mm. dried and somewhat curled, and was given to me by Mr. W. L. May. All the specimens are about the same size, four in all, and must have been double the size when alive.

Habitat.—All the four known specimens were dredged by Mr. W. L. May in D'Entrecasteaux Channel, Southern Tasmania, in 9–10 fathoms. One measuring 42 x 21 mm. was taken at the same depth as the others out of the centre of a sponge, so it is evident that they inhabit sponges as does its near ally *A. speciosus*, but whether the sponge is simply a place of safety or is also a food supplier, must be left to future investigation.

Confirmatory of the foregoing, Mr. May sends me the following note:—"A young fisherman and scallop dredger, who was with me when I obtained the specimens, knew it well and said he had often seen them in sponges."

Conclusion.—This species at first sight closely resembles *A. speciosus* H.Ad., but is easily separated from that species by its minute, extremely slender, girdle spicules and the more elongate character of the squamose granules.

Acanthochiton spongialis glauerti n. subsp.

Introduction.—I am indebted to Mr. L. Glauert for the opportunity of examining and describing a little *Acanthochiton* which he took out of a sponge which he picked up on the beach at Cottesloe, Perth, W.A., in June, 1923. The discovery was particularly opportune, for I had been hesitating for some time about describing the foregoing species, of which all the four known specimens are very senile shells. There was the possibility, though somewhat remote, that the character of the girdle spicules might be due to senility.

Mr. Glauert's specimen demonstrates that the peculiar character of the girdle spicules is constant, even in the very juvenile form.

Although at first it seemed best to describe this western form as a variety of the preceding species, the careful examination of the other specimens that Mr. May has kindly placed in my hands determines me to give it sub-specific rank chiefly on the very marked character of the tail valve. One even anticipates that when more adult specimens are available that it may be found to deserve full specific rank.

General appearance.—Valves very small in proportion to the girdle, which latter is very broad and spongy looking, encroaching completely between the valves and densely clothed with minute, slender spicules. The general colour is buffish grey. The dorsal area is narrow.

Colour of valves.—The ground colour of all valves is transparent white, the upper fourth of anterior valve is bright pink, and the beak and edges of the dorsal area of other valves is also bright pink. The squamose granules of the radial ribs in the anterior valve, the diagonal ribs in median valves and the six radial ribs of the posterior valve, are generally opaque (porcelain) white but in some cases are pink.

Sculpture.—The radial ribs in the end valves and the diagonal ribs in the median valves are much raised and defined by large, elongate somewhat arched granules. There is a single rib on each side in the median, five in the anterior and six behind the mucro in the posterior valves. The rest of the sculpture consists of round, squamose granules placed in longitudinal rows—in this one respect very similar to *A. speciosus.*

Measurement.—In spirit specimen 17 x 8 mm. (W.A. Mus. No. **10399**).

Differences.—Differs from *A. spongialis* Ashby (sens. str.) in the general sculpture being more rounded, in the sculpture of the ribs being opaque white and less flat, and in having six very well defined radial ribs behind the mucro in the posterior valve.

Differs from *A. speciosus* H. Ad. in the fact that the girdle spicules are minute and slender and also in the ribbing.

Differs from *A. subviridis* Torr. in having a single diagonal rib in the median valves and in the rib granules being less confluent and also in having a narrow dorsal area.

Differs from *A. costatus* Ad. and Ang. and *subviridis* Torr. in the encroachment of the girdle between the valves separating them from one another, also in having the girdle densely clothed with minute spicules.

EXPLANATION OF PLATE I.

Fig. 1. *Acanthochiton spongialis* Ashby: Shows great width of girdle in proportion to valves. Total length 38 mm.

Fig. A. *A. spongialis*: Anterior portion of animal showing five valves. Width of valve 4 is 17 mm.

Fig 2. *A. spongialis glauerti* Ashby: Same magnification as Fig. 1. Total length 17 mm.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth

A Critical Examination of the Einstein Eclipse Tests by Professor **A. D. Ross,** M.A., D.Sc., F.R.S.E.

(*Read* September 11, 1923. *Issued* October 16, 1923.)

From his restricted theory of relativity, Einstein in 1911 predicted * that stars observed in the field surrounding the totally eclipsed sun should be displaced outwards by an amount 0·83sec./d, where d is the angular distance of the star from the sun's centre expressed in terms of the sun's radius. The value was corrected later to 0·87sec./d. The generalised theory † increased the amount of the deviation to 1·745sec./d, being double the value which would follow from a simple hypothesis that the mass of the electromagnetic energy of light is subject to gravitation.‡

Attempts to apply this crucial test of Einstein's theory were made at the following eclipses:—1914, August 21 (Russia); 1918, June 8 (U.S.A.); 1919, May 29 (Brazil and Africa); 1922, September 21 (Australia and Christmas Island); 1923, September 10 (U.S.A. and Mexico).

In 1914 the Lick Observatory expedition failed through cloudy weather, while the Babelsberg expedition was withdrawn owing to the outbreak of war. The 4-inch 15-ft. lenses used by the Lick party in 1918 unfortunately did not give a sufficiently flat field, and the measures of the plates were altogether inconclusive. The mean of the measurements seemed if anything to support the half deflection.§

In 1910 two British expeditions made observations at Sobral in Brazil and at Principe Island in the Gulf of Guinea. The results (expressed in seconds of arc) were ||:—

Station.	Instrument.	Plates.	Stars.	Result.	Probable Error.
Sobral	Astrograph	18	6 to 12	0·86	?
,, ...	,,	18	5	0·93	?
,, ...	4-inch lens	7	7	1·98	0·12
Principe	Astrograph	16	4 to 5	1·61	0·30

The British astronomers considered that the probable errors calculated from the deviations of individual observations from the mean did not in all cases represent the whole uncertainty.

* A. Einstein, Ann. d. Physik, xxxv., p. 898 (1911).
† A. Einstein, Ann. d. Physik, xlix., p. 769 (1916).
‡ A. D. Ross, Proc. Roy. Soc. W.A., v., p. 93 (1920).
§ W. W. Campbell, Observatory, xlii., p. 298 (1919).
|| F. W. Dyson, A. S. Eddington, C. Davidson, Memoirs R.A.S., lxii., Appendix (1920); Phil. Trans. Roy. Soc., A. ccxx., p. 291 (1920).

Systematic errors were probably introduced through distortion of the coelostat mirror *, and imperfection of the star images diminished the value of the Sobral astrographic measures. On the whole the tests favoured the Einstein prediction. †

In 1922 observations were made by the Lick Observatory, Toronto University, and Kodaikanal Observatory expeditions at Wallal, W.A., by the Adelaide Observatory expedition at Cordillo Downs, S.A., and by the Sydney Observatory party at Goondiwindi, Queensland. The Adelaide Observatory plates have been forwarded to the Royal Observatory, Greenwich, for measurement, and the work is still in progress. The Kodaikanal ‡ and Sydney attempts have been abandoned owing to the photographs taken having proved unsatisfactory.

The Canadian party under Professor Chant obtained two eclipse photographs $E1$ and $E2$ with an 11-ft. camera working at $f22$ §. Comparison plates $N1$ and $N2$ of the eclipse field were taken by Dr. Trumpler in May, 1922, at Tahiti, with the same camera, and also an "intermediate plate" M of the same region photographed through the glass, the film side of the plate in the holder being turned away from the lens. Hence plate M could be superimposed on any of the plates $E1$, $E2$, $N1$, $N2$, film to film, with corresponding stellar images in close proximity. The images on M were thus used as "intermediates" to compare the positions on $E1$ and $N1$ or $E2$ and $N2$. Lateral and rotational displacements of one plate relative to the other, and differences in scale value (due to change in focal length of the camera) all result in apparent displacements of the stars under different laws to the Einstein effect, and these effects could thus be eliminated ‖. Allowance was made for differential refraction and aberration, and then, assuming the existence of the Einstein term, its value at the sun's limb was deduced by the method of least squares from the resultant equations. About 25 stellar images were obtained, but only 19 were subjected to measurement. The measurements of one star were omitted from the computations as altogether unsatisfactory, and of the 18 others, three gave results which were evidently considerably in error. The results ¶ were :—

Using 18 stars : 1·38 and 2·09 sec., mean 1·73 sec.
Using 17 stars : 1·73 and 2·17 sec., mean 1·95 sec.
Using 16 stars : 1·73 and 2·75 sec., mean 2·24 sec.
Using 15 stars : 1·28 and 2·18 sec., mean 1·73 sec.

The results are somewhat discordant, but clearly indicate an Einstein value of 1·745 rather than the half value of 0·87 second.

* H. N. Russell, M.N. R.A.S., lxxxi., p. 154 (1920).
† W. H. Pickering, Popular Astronomy, xxx., No. 4, p. 1 (1922).
‡ Kodaikanal Observatory Bulletin, p. 72 (1923).
§ C. A. Chant, Journ. Roy. Astr. Soc. Canada, xvii., p. 1 (1923).
‖ Smithsonian Report for 1919, p. 133.
¶ R. K. Young, Journ. Roy. Astr. Soc. Canada, xvii., p. 129 (1923).

Dr. W. W. Campbell of the Lick Observatory used a pair of 15-ft. cameras working at *f*36 and a pair of 5-ft. cameras working at *f*15*. The measurements of the plates taken with the 5-ft. cameras have not yet been completed, but the 15-ft. camera plates have afforded a decisive result. With exposures of about two minutes, the plates recorded in all 92 measurable stars, ranging from 4·3 to 10·8 photographic magnitude, the number of stars used on individual plates varying from 62 to 85 †. These plates give values of 1·80, 1·48, 1·85, 1·76 second, with a mean value of 1·72 second and a probable error of only 0·11 second. This result is little over one per cent. less than Einstein's predicted value of 1·745 second. Calculation of the precision index and hence of the probability integrals shows that the chance of the correct value being 0·87 second is less than one in a thousand.

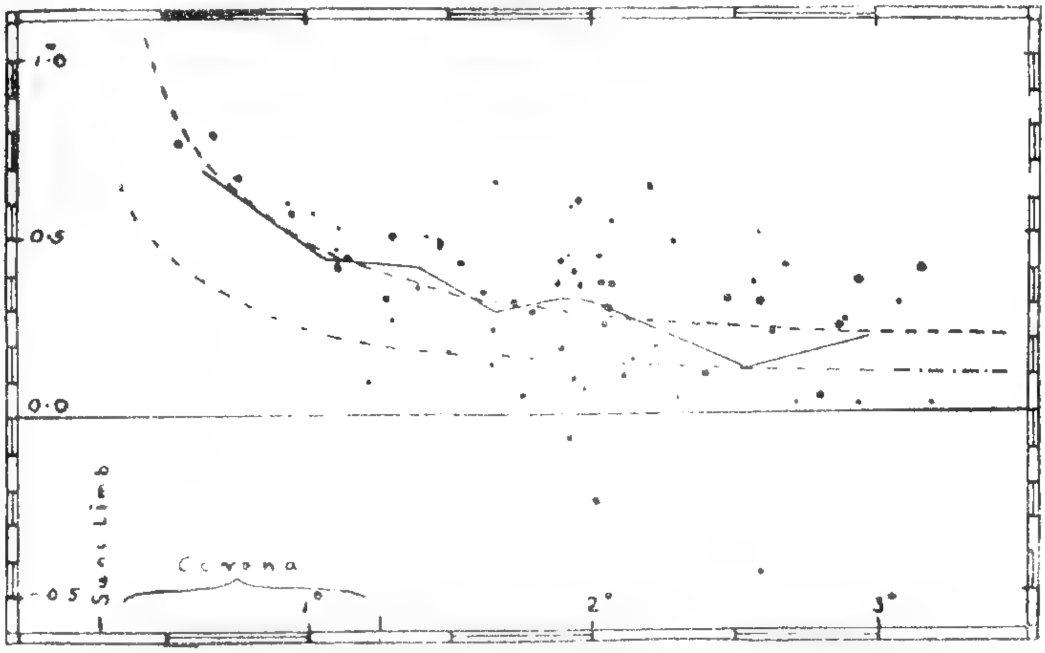

Fig. 1. Radial Displacements of Eclipse Stars as a function of their angular distance from the sun's centre.

Fig. 1 shows the radial displacement of individual stars, and the irregular continuous line connects the group means of the weighted observed displacements. The dotted line represents Einstein's predicted values, and the chain line lower down in the diagram indicates the displacements which would be found on a Newtonian theory if light were subject to gravitation. It is to be noted that the Lick Observatory computations did not assume an Einstein term in the observed displacements. The displacements of the stars were measured, corrected for the effects of proper motion, annual parallax, differential refraction, aberration, and

* W. W. Campbell, Publ. Astr. Soc. Pacific, xxxv., p. 11 (1922).
† Lick Observatory Bulletin, p. 346 (1923).

inclination of the plate normal to the optical axis. In the measurements the displacements of the stars were taken relative to all those at distances exceeding two degrees. Having established from these relative displacements the existence of the Einstein effect, a correction was applied to reduce the relative displacements to absolute values.

Fig. 2 shows, magnified 3,000 times, the measured displacements of 50 of the 92 stars, viz., of those which appear on several plates and give fair images. Only the positions of the other stars are indicated. The dotted line indicates the farthest extent to which the corona can be traced on the negatives. The brightness of the corona prevented satisfactory observations of any stars within 15 minutes of the sun's limb in polar directions or within 50 minutes of the limb in equatorial directions.

Star B.D. 2·2509 shows a peculiar discrepancy from theory on the Lick Observatory plates, and star B.D. 1·2628 on the

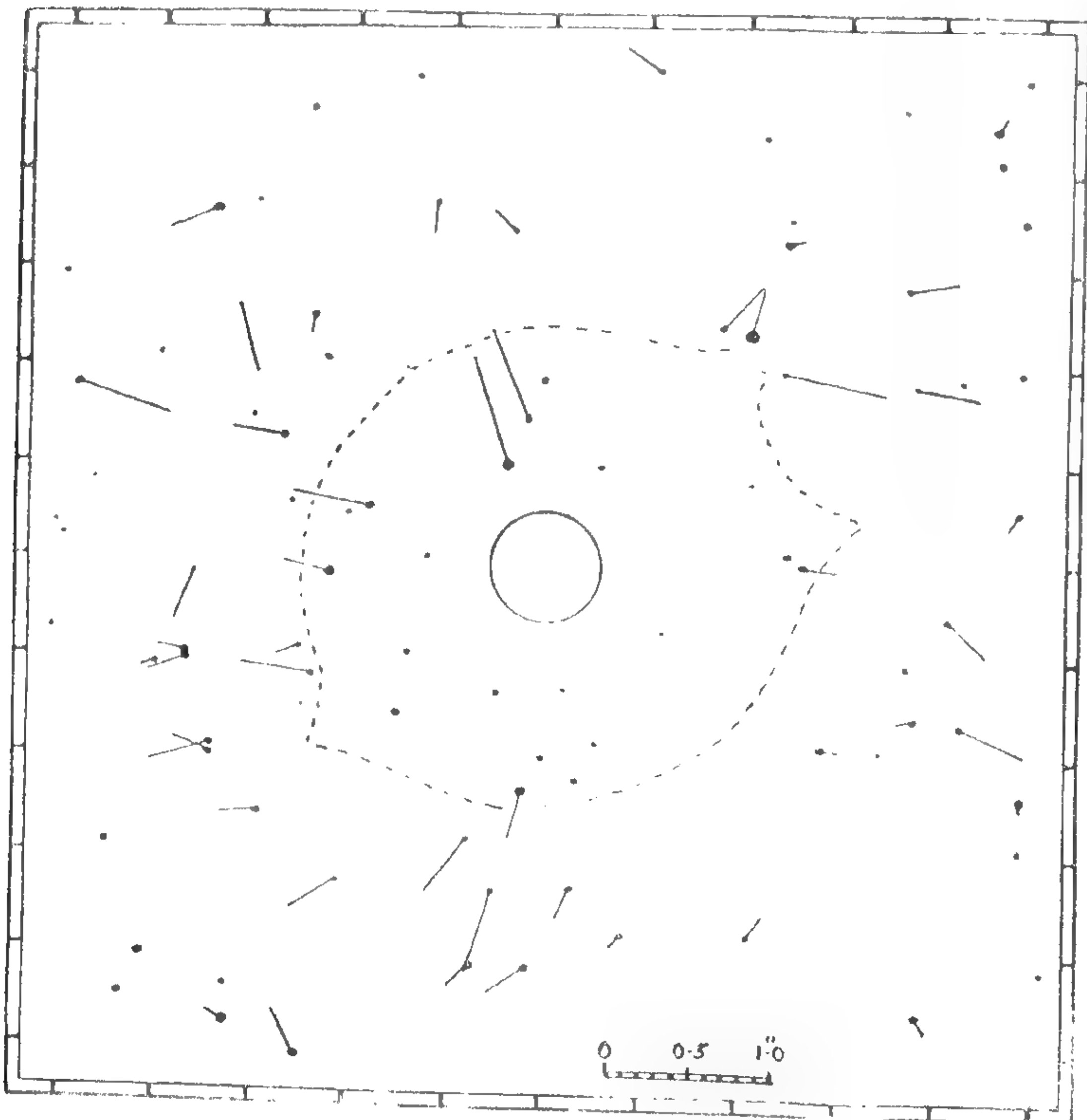

Fig. 2. Observed Radial Displacements of Eclipse Stars.

Canadian plates. Thus for B.D. 2·2509 the Einstein prediction is + 0·02. The observed displacements are — 0·72 (Lick Obs.) and + 0·35 (Canadian). For star B.D. 1·2628 theory gives + 0·81, as compared with observed values + 1·46 (Canadian) and + 0·76 (Lick Obs.). As the discrepancies are not common to the plates of both expeditions, they must be due to some experimental or observational effect, such as local shrinkage of the plate film.

The Lick Observatory's photographic programme differed from that of the Canadian party in that a check star field (surrounding 70 Ophiuchi) was photographed superimposed on the test star field both on the eclipse plates E and on the comparison plates N. As this check field was far from the sun in all cases, its star images could not show a displacement between the E and N plates due to an Einstein effect. As a matter of fact no displacement of this kind was found, but there was a slight reversed effect in the case of stars nearer the centre of the plate.

Eclipse tests of the Einstein effect might be invalidated by—

1. Distortion of optical parts of the apparatus *.

2. Systematic errors in setting with the measuring microscope on the star images owing to the corona causing a gradation of the intensity of the background †.

3. Systematic distortion of the photographic film in drying after development and fixation ‡.

4. Abnormal refraction in the earth's atmosphere during totality §.

5. Refraction in an extended solar atmosphere ‖.

6. Yearly refraction ¶.

In the determinations made by the Lick Observatory and the Canadian party, error under the first source was reduced to a minimum by using equatorially mounted cameras and so obviating the necessity for coelostat mirrors. Errors under 2 were eliminated in the case of the Lick Observatory's measurements by use of the check star field, while the same device enabled errors under 3 to be estimated. The small reversed effect found with the check region stars superimposed on the central part of the eclipse plates is probably due to the more rapid drying and consequent shrinkage of the parts of the film blackened by the corona. Allowance for the effect increases the value of 1·72 second obtained for the Einstein constant to about two seconds **. Errors under 4 and

* H. N. Russell, M.N. R.A.S., lxxxi., p. 154 (1920).
† M. Wolf, Astr. Nachr., ccxii., p. 181 (1920).
‡ F. Ross, Ap. Journ., lii., p. 98 (1920).
§ A. Anderson, Nature, civ., pp. 354, 372, 393, 436, 468, 563 (1919–20).
‖ H. F. Newall, M.N., R.A.S., lxxx., p. 22 (1919), Observatory, xlii., p. 428 (1919), xliii., p. 145 (1920). W. Anderson, Astr. Nachr., ccxviii., p. 251, (1923).
¶ Courvoisier, Astr. Nachr., ccxi., p. 305 (1920).
** It is to be noted that this correction is obtained by extrapolation, and it should not be taken as indicating more than the nature and order of magnitude of the effect.

5 are extremely unlikely when the star images are sharp, when the displacements vary closely in accordance with the Einstein law, and when the law is obeyed equally well by stars viewed through the corona and by stars appearing beyond its visible limits. Courvoisier's yearly refraction effect is quite unknown for stars near the sun. An effect rising from zero at the sun's limb to about 0·4 second at a distance of two degrees or more would, when added to the Einstein effect, bring theory and observation into still closer agreement.

By Authority: Fred. Wm. Simpson, Government Printer, Perth.

A New Genus of Fresh-water Isopoda, allied to Phreatoicus.

By Professor **G. E. Nicholls**, D.Sc., F.L.S., and Miss **D. F. Milner**, B.Sc.

(*Read* September 11, 1923. *Issued* December 3, 1923.)

The specimens, upon which the following description is based, were first taken by one of us on the occasion of an excursion made by members of this Society to the Lesmurdie Falls in the Darling Range, on August 11, 1923. Prior to this date there had been a period of prolonged and very heavy rainfall, and water was welling up strongly from numerous springs and soaks. Some twenty specimens, including one female, were taken in a small pool a few inches deep and less than a square yard in area, supplied by a small spring just below the falls.

A fortnight later, when the spot was revisited after a dry period, only about half a dozen in all were obtained, although a careful search was made. The search was extended to the entire hillside, and included numerous pools formed by the many winter soaks, but failed to reveal the animal in any other place. Its bleached appearance, blind condition and elongated shape suggest that it is a subterranean form which gets carried from crevices undergound by the rush of water during the rainy season. It appears to be able to hold on strongly but is unable to swim, though walking well and quickly. Sayce's account (1899) of the related form *Phreatoicoides* suggests that it, too, might be a subterranean form washed out from underground and collecting in similar pools where the slight damming up of water enables some to escape being swept away into the swifter running stream. No member of the family *Phreatoicidae* had been recorded from Western Australia until a few months ago, when a description of an undoubted *Phreatoicus* was read before this Society by Glauert (1923). The specimen now described, while agreeing in many important respects with that form is, in other features, clearly intermediate between that genus, *Hypsimetopus* and *Phreatoicoides*, and not to be assigned to any of these. Associated with it were two small Amphipods, not yet identified, which also occur quite sparingly.

HYPEROEDESIPUS gen. nov.

Body long, sub-cylindrical, slightly compressed. Cephalon relatively large, slightly deeper than the first free segment. This is much shorter than the succeeding segments, which are sub-equal in length. Pleon distinctly shorter than in *Phreatoicus*, but not so short as in *Hypsimetopus*, and half as long again as in *Phreatoicoides*; pleura scarcely produced, the pleopods entirely exposed.

Upper antenna short; lower antenna long, with flagellum. Mandible with an appendage. First peraeopod terminates in a subchelate hand in both sexes; in the male this is of moderate size and bears upon its dorsal surface a well-developed projection, absent from the smaller hand of the female. Exposed pleopods intermediate in form between those of *Phreatoicoides* and *Hypsimetopus*, being much narrower than those of the latter and shorter than those of the former. Epipodites absent from 3rd, 4th and 5th pleopods. The tail-piece, formed by the united telson and last pleon segment, is relatively long and distinctly constricted off from the fifth pleon segment. Uropods as long as the tail-piece and projecting well behind posterior margin of telson. Telson truncate.

Remarks. Most nearly resembling *Hypsimetopus* in the general form of the body, it differs markedly from that genus in a number of particulars. In the proportions of cephalon and first segment it agrees much more nearly with *Phreatoicus* (*P. australis*). The constriction between 5th and 6th pleon segments is much more marked than in *Hypsimetopus* but much less than in *Phreatoicoides.* It agrees with the latter, however, in the absence of epipodites.

Hyperoedesipus may readily be distinguished from *Phreatoicus* and *Phreatoicopsis* by the exposed condition of the pleopods. It differs from both of these and from *Hypsimetopus* in the absence of epipodites from the last three pairs of pleopods. From *Hypsimetopus* and *Phreatoicoides* it differs in the extreme narrowness of the first free segment. It may further be distinguished from *Phreatoicoides* by the much greater proportional length of the pleon and the shape of the mature grasping hand in the male. Plumose setae, so abundantly present in *Hyperoedesipus,* are said to be altogether absent in *Phreatoicoides.*

In the sum of its characters, therefore, *Hyperoedesipus* seems to occupy a position near to *Phreatoicus* (*P. australis*) but intermediate betwen that genus and *Hypsimetopus* and *Phreatoicoides.* Reference to the table appended will serve to make clear these several resemblances and differences.

Hyperœdesipus plumosus. sp. nov.

Specific diagnosis. Body slender, sub-cylindrical, slightly compressed, surface smooth with sparsely scattered setae. Eyes not formed. Pleura of pleon scarcely produced, their inferior margins fringed with small spiniform setae. Taking cephalon and peraeon as 100, the pleon and telson measure 53. Fifth segment of pleon about half the length of the anterior four. Sixth pleon segment deeper than those preceding and measuring more than half the length of the five anterior segments.

Upper antennae of 7-8 joints less in length than peduncle of lower antennae. Lower antennae about half length of body, peduncle of five joints, first two short and sub-equal, third and fourth longer, fifth as long as the two latter combined. Flagellum of 21-27 segments. Legs long and slender, the posterior series of three approximately 1⅓ the length of those in anterior series. First pair of peracopods sub-chelate, largely developed and, in the mature male, with a notable projection upon anterior surface. Telson truncate. Uropoda with the peduncles stretching considerably beyond the telson, rami not as long as peduncle, the inner one longer than the outer and slightly curved inwardly. Plumose setae abundantly developed on the pleopods.

Colour whitish, the animal translucent, the intestinal tract being clearly visible through the transparent body wall.

Length—male 10 mm. Female with brood pouch (only one specimen taken), 6 mm.

Habitat. Found sparingly in a pool of a square yard or less in extent, fed by a spring and situate just at the foot of the Lesmurdie Falls, in the Darling Range, W.A.

Detailed Description. The male specimens which were examined varied in length from 7 mm. to 10 mm., the female with eggs in incubatory pouch measured 6 mm. In both sexes the body is subcylindrical and practically of uniform breadth and depth throughout the whole length. The pleon is but slightly deeper than the peraeon, the pleura in this region being extremely short and not appreciably produced to protect the pleopods. The surface of the body is smooth with sparsely scattered setae. Specimens preserved in spirit undergo a certain contraction whereby the softer intersegmental regions are concealed.

Head. The head (Pl. II, 1b) is much longer than the following segment, slightly deeper and somewhat wider. The dorsal surface is convex and curves down antero-laterally, presenting a concave surface for articulation with the mandible. There is no trace of the eyes and but few setae occur on the dorsal surface.

Peraeon. This consists of seven segments, not all of equal size (Pl. II, 1a). The first free segment being less than half as long as the second, while the succeeding segments are subequal. Setae occur sparsely on all the segments and fringe the inferior margins. They are scattered singly and do not occur in tufts as is the case in some species of *Phreatoicus.*

Pleon. The five anterior segments are distinct but the sixth is so completely fused with the telson as to be indistinguishable (Pl. II, 1a). Segments 1-4 are quite short, being less than half the length of a peraeon segment. The occurrence of very narrow pleura

makes them slightly deeper than the peraeon segments, each pleuron extending slightly downward and posteriorly, to overlap the succeeding segment, but they are quite insufficient to conceal the pleopods. Their inferior borders are convex and sparsely fringed with spinules. The fifth segment is approximately twice as long as the preceding segment and its anterior border is equal to that in depth but the pleura on this segment are better developed and give to it a fictitious depth, serving to conceal largely the distinct constriction between segments five and six. The united telson and sixth segment form the "tail-piece" (Pl. V, 10, 11). Its dorsal margin is slightly convex. In lateral view it is seen to turn abruptly, almost vertically downward and the posterior margin, for about half the depth of the segment, is nearly straight. Seen from above, it presents a convex outline, deeply notched (Pl. V, 11) in the middle line, the indentation marking the position of the anus which is terminal. The inferior margin, which is nearly straight for about three-fourths of the length of the segment, is bent upwards nearly vertically for approximately one-third of the height of the piece, at the articulation of the uropod. Posteriorly to the insertion of the uropods the convex inferior margin of the tail-piece curves gently upwards to meet the posterior margin somewhat obtusely. The whole surface is sparsely set with setae.

Tail-piece. This, with the uropods, differs both in relative size and in shape from the corresponding structures of any of the existing allied genera (fig. 1). The very obvious constriction at its

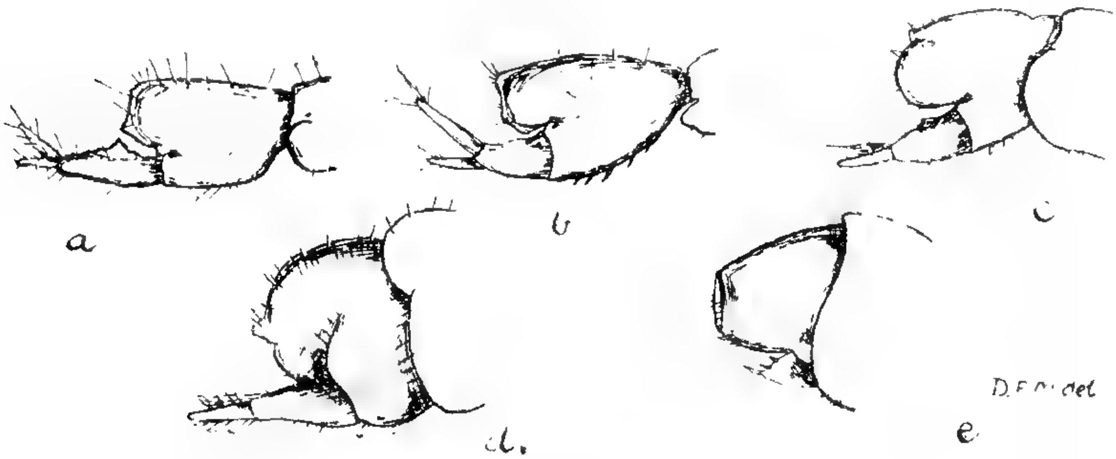

Fig. 1.

anterior margin distinguishes *Phreatoicoides* (fig. 1b); *Phreatoicus* (1d) and *Hypsimetopus* (1c) are marked by the possession of a telson of sub-conical form, while in *Phreatoicopsis* (1e) the telson is abruptly truncate and is further peculiar in the relative shortness of the uropods. *Hyperoedesipus* (1a) lacks all of these distinctive characteristics but seems most nearly to approach the condition of *Phreatoicoides.*

First antennae. (Pl. IV, 3a.) These are short, not extending to the distal end of the peduncle of the second antennae. They are divided into sometimes eight, more often seven joints. The first joint is small and without setae, the second somewhat longer with one or two fine setae, and the third only slightly greater in length than the first joint and narrower than the second. The remaining joints show a gradual increase in length until the penultimate is reached, this being both longer and stouter than the second. The terminal joint is very small and forms a rounded knob. It bears a circlet or tuft of fine hair-like setae. On the other segments sensory setae occur but sparsely.

Second antennae. (Pl. IV, 3b.) These are about half as long as the body. The peduncle consists of five joints, of which the first two are short and sub-equal, the third and fourth longer, and the fifth as long as the two latter combined. Each joint is sparsely setose whilst from the distal end of the fifth segment springs a series of very long setae. The number of joints composing the flagellum is not constant, varying from as few as 21 to as many as 27. Almost invariably the number of these joints is different on the right and left side of the same specimen, the right in most cases possessing fewer joints than the left. The first joint of the flagellum is twice as long as the succeeding joints, which are equal in length but become more slender towards the extremity. At the distal end of many of these segments there is a circlet of short setae, the terminal joint bearing a tuft of three or four longer setae.

The *upper lip* (Pl. IV, 4) is relatively large and is slightly broader than long. Its distal margin is clothed with short fine setae and has a shallow median notch.

The *mandibles* do not appear to differ in any important respect from those of *Phreatoicoides*. As is usual, the mandibles of opposite sides are slightly dissimilar in the cutting edges. The left mandible (Pl. IV, 5) has two rows of teeth, the outer row consisting of four sharp and strong teeth, the inner row of four smaller teeth. A molar tubercle (*m.t.*) is well developed and, distal to it, is a short process set with eight stout setae, some of which are plumose. There is but a single row of four strong sharp teeth to the cutting edge of the right mandible.

The *lower lip* (Pl. IV, 8) is a short bilobed structure, broader and shorter than the upper lip. The lobes are not as distinct as in other *Phreatoicidae*, a slight concavity on the ventral margin alone separating them distally. The entire ventral margin is densely fringed with inwardly directed setae. A median ridge on the posterior aspect appears to be well developed; it is probably the homologue of a similar structure described by Chilton in *Ligia exotica*

(1916), but has apparently not been recognised in other *Phreatoicidae.*

The *first maxilla* (Pl. IV, 6) resembles in outline that of *Phreatoicoides* and *Phreatoicus australis.* It bears two lobes, the outer shorter and stouter with truncate end and fringed with short curved spines. On its outer border are a few setae. The inner lobe is more rounded distally and carries, at its extremity, four long plumose setae with which are mingled a number of simple setae.

The *second maxillae* (Pl. IV, 7) show a basal portion produced into a rounded lobe at the inner distal end. External to this are situate two lobes, similar to one another and somewhat longer than the inner lobe. The end of both of these is obliquely truncated and bears numerous pectinated curved setae as well as a number of long simple spiniform setae.

The *maxillipedes* (Pl. IV, 9) are large and similar to those of *Phreatoicoides.* The coxa bears laterally a large flat plate (epipodite) which does not extend as far as the distal end of the ischium. The basis is three times as long as broad and has attached to its inner margin an accessory flattened plate which reaches to the end of the merus. Its dorsal margin is closely set with fine setae, the more distal of which are pectinated. Ischium, merus, carpus and propod do not differ materially from the corresponding structures in *Phreatoicoides.* The dactyl, however, is rather swollen, ends bluntly and has both inner and outer margins convex.

First Peraeopods. In the male these form large well developed sub-chelate gnathopods (Pl. V, 12). The basis and ischium are subequal in length, narrowed at their junction with the following segment. A few long setae occur on the posterior distal margin of the basis; the ischium has two setae arising from the middle of the posterior and anterior borders. The merus, which is about half as long as the ischium, is sub-triangular in outline; distally it bears a number of long hair-like setae. The carpus is also sub-triangular in shape, the posterior margin in this case forming the base of the triangle. From this margin spring a couple of spiniform setae. The propod of the mature male is large and presents a very characteristic shape entirely distinct from the propod of any of the *Phreatoicidae* hitherto described. Its anterior margin is produced upwards, almost vertically, and stretches proximally more than half the length of the ischium forming a large swelling on the anterior border of the propod. In the immature male the anterior border is but slightly convex and curves distally to articulate with the dactyl. At its proximal end the posterior margin is convex and bears numerous stiff spiniform setae; distally its outline is concave and this part of the palm is almost bare of setae. The dactyl is actually longer than the propod

but much narrower and curves slightly inwards to terminate in a strong claw-like spine. Such a spine is figured in *Phreatoicoides* but not described; it does not appear in the figures of other genera of *Phreatoicidae.* A few short and stiff setae are scattered over the surface of the dactyl.

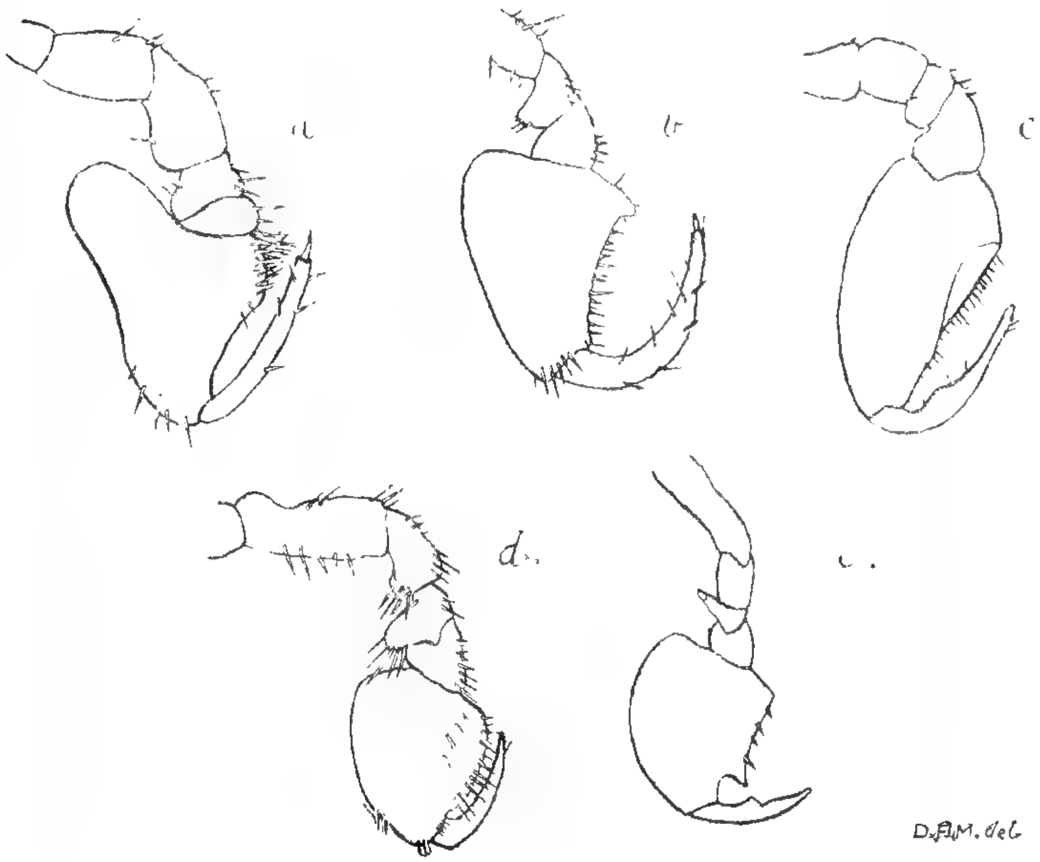

Fig. 2. First peraeopod of *Hyperoedesipus* (a); *Phreatoicoides* (b); *Hypsimetopus* (c); *Phreatoicus australis* (d); *Phreatoicopsis* (e).

In the female the parts of this limb are similar with the exception of the propod, which is smaller (Pl. V, 13), and lacks the notable swelling on the convex anterior margin. The palm is much more sparsely setose and the dactyl is shorter, not quite equalling the propod in length.

Second and third peraeopods. (Pl. V, 14.) The basis and ischium are similar to those of the first peraeopod and equal in length to the merus, but the latter is much more constricted proximally. Its anterior margin is produced at its distal end to overlap the carpus, the projection bearing several stout setae. The carpus is similar and sub-equal to the merus, a few setae arising from its posterior margin and a distal cluster from the anterior margin. The propod is sub-rectangular and is equal in length to the carpus but slightly narrower, with four or five setae posteriorly. Its anterior margin is but sparsely setose with a distal tuft. The short dactyl is borne

almost at a right angle to the propod and ends in a sharp tooth-like spine.

The *fourth peraeopod* bears a general resemblance to the second and third, but the segments are relatively shorter and the appendage is modified to form a grasping organ. The convex margins of the propod are set with stout spiniform setae and the dactyl, markedly curved, is directed so as to lie almost along the propod. In this sexual differentiation of the fourth peraeopod, *Hyperoedesipus* differs from *Phreatoicoides* (in which it is altogether lacking) and much more closely resembles the condition met with in *Phreatoicus australis*.

The first four pairs of appendages on the peraeon form an anterior series differing in structure from the last three pairs. They arise from the middle or even the anterior portions of the segments and in them the dactyl is backwardly directed, whereas the three more posterior appendages are longer, arise from the posterior region of their related segments and show the dactyl forwardly directed.

The *fifth, sixth and seventh peraeopods* are similar to one another, but each is longer and proportionately larger in all its parts than the preceding limb. The seventh, the last of the posterior series of three, is approximately $1\frac{1}{3}$ the length of the longest of the limbs of the anterior series.

The *pleopoda* are large and well developed. There are five pairs, all branchial in function and hanging vertically from the ventral surface wholly unprotected by pleura. In this respect *Hyperoedesipus* resembles *Phreatoicoides* and *Hypsimetopus* and differs markedly from *Phreatoicus*.

The *first pleopod* (Pl. V, 16). The protopodite is sub-rectangular in outline and, like the narrow elliptical endopodite, is wholly devoid of setae. The exopodite, also elliptical in shape, is $1\frac{1}{2}$ the length of the endopodite and about twice its breadth. The margin is entire and is fringed with long plumose setae, only a few (three or four) at the proximal end being simple.

The *second pleopod* (Pl. V, 17). The protopodite is larger and stouter than in the preceding limb and bears distally, on its inner margin, a number of setae, some of which are short and hooked. The endopodite is attached by a thick peduncle from which, in the male, arises the penial filament. This is a narrow, almost sickle-shaped process tapering to a point, much as in *Phreatoicoides*, but bearing at its extremity two very long simple setae. The exopodite is more or less oblong and has a smaller lobe arising towards its distal end projecting freely beyond the main lobe. The margin

is closely set with long setae, all of which are plumose with the exception of those few situate on the short inner margin. In the female this appendage is similar but lacks the penial filament.

The *third, fourth and fifth pleopoda* are generally alike, but decrease in size gradually from the third to the fifth. The so-called epipodite found in *Phreatoicus, Phreatoicopsis* and *Hypsimetopus* is absent in *Hyperoedesipus*, which thus resembles *Phreatoicoides* alone of the described *Phreatoicidae*. The endopodite decreases in size until, in the fifth pleopod, it is about one-third only of the length of the exopodite, which in this limb is relatively much broader (cf. *Hypsimetopus*) and has the terminal lobe distinctly smaller. The margins are fringed with long setae which are plumose, with the exception of those on the inner margin and a few on the outer proximal margin.

The *uropoda* (Pl. V, 10, 11) are strongly developed. The peduncle stretches considerably beyond the telson, and the lower margin is slightly curved upwards and sparsely setose. The upper margin is markedly serrated and bears a few setae. The outer ramus is two-thirds the length of the peduncle, is styliform, ending in an acute point, and bears numerous spiniform setae. The inner ramus arises from the dorsal surface of the peduncle and is slightly longer and thicker and curved inwards almost to meet its fellow of the opposite side. In life, however, the uropods are carried outwardly, directed at an angle of about 45° to the long axis of the body, and suggest the extended pincers of the earwig.

The solitary gravid female (Pl. III.) taken, measures 6 mm. in length and has a well developed incubatory pouch. This occupies the region beneath the segments 1-5 of the peraeon and extends ventrally to the distal extremity of the ischium of the third peraeopods. It appears to be formed by three pairs of thin transparent lamellae (oostegites) which arise from the inner side of the basal joints of the third, fourth and fifth pairs of peraeopods and overlap to enclose a spacious chamber in which the eggs are carried. In the figure the first pair of oostegites seem to have been displaced ventrally, the lamellae having probably been loosened. The lamellae are sub-spherical in outline, much as in *Phreatoicoides*, with entire convex margins.

Sexual differences. The adult female is distinctly smaller than the male and, in addition to bearing the incubatory pouch, differs externally in the following characters:—First peraeopod lacking the well developed clasping hand, fourth appendage not modified to form a grasping organ, second pleopod without a penial filament.

EXPLANATION OF PLATES.

II.

1a.—Lateral view of *Hyperoedesipus plumosus* (male). Only the appendages of right side shown with the exception of the pleopods and 1st pair of peraeopods.

1b.—Cephalon and adjacent parts enlarged.

- *a*—1st antenna.
- a_2—2nd antenna.
- *Md.*—mandible.
- *Mxp.*—maxilliped.
- *Ppd.*—portion of 1st peraeopod.

III.

Lateral view of *Hyperoedesipus plumosus* (female).

IV.

Appendages of *Hyperoedesipus plumosus.*

3a.—1st antenna.
3b.—2nd antenna.
4.—Upper lip.
5.—Left mandible.
- *p*—palp.
- *mt.*—molar tubercle.

6.—1st maxilla.
7.—2nd maxilla.
8.—Lower lip.
9.—Maxilliped.
- *ep.*—epipodite.
- *ac. l.*—accessory lobe.

V.

Appendages and tail-piece of *Hyperoedesipus plumosus.*

10.—Lateral view of tail-piece and uropod.
- *a.*—anal opening.

11.—Dorsal view of same.
12.—1st peraeopod (male).
13.—1st peraeopod (female).
14.—2nd peraeopod.
15.—7th peraeopod.
16.—1st pleopod.
17.—2nd pleopod (male).
- *pf.*—penial filament.

18.—5th pleopod.

All figures drawn with the aid of camera lucida, Plate II, 1a, from a living specimen.

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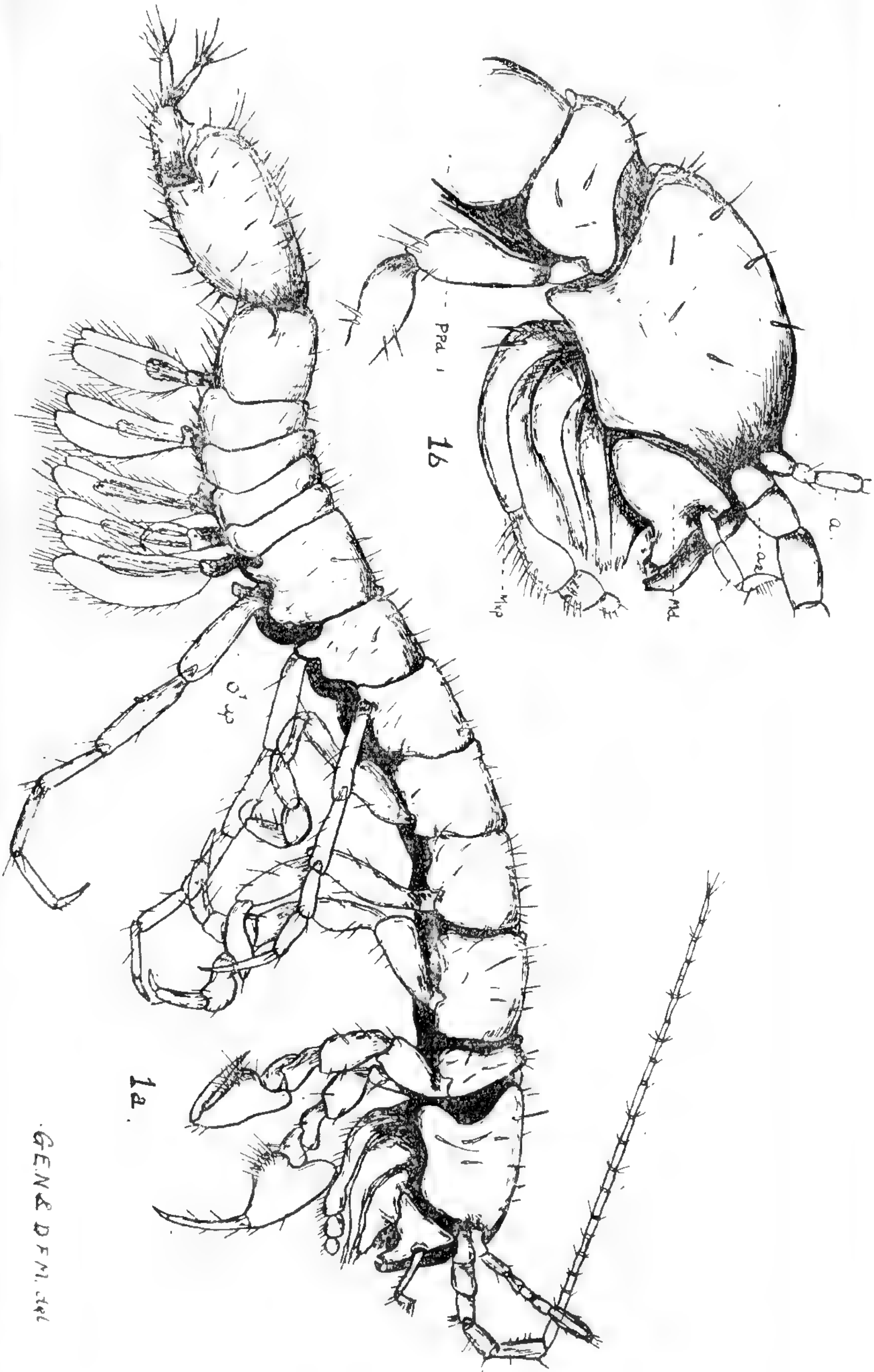
SYSTEMATIC POSITION OF HYPEROEDESIPUS.

	Hypsimetopus.	Phreatoicopsis.	Phreatoicus.	Hyperoedesipus.	Phreatoicoides.
Ratio of $\frac{\text{Pleon and Telson}}{\text{Cephalon and Peraeon.}}$	$\frac{45}{100}$	$\frac{60}{100}$	$\frac{58 - 63}{100}$	$\frac{53}{100}$	$\frac{36}{100}$
First segment of Peraeon	Equal in length to succeeding segment	More than $\frac{1}{2}$ length of succeeding segment	$\frac{1}{3}$ - $\frac{1}{2}$ as long as succeeding segment	Less than $\frac{1}{2}$ length of succeeding segment	$\frac{2}{3}$ length of succeeding segment.
Constriction between segments 5 and 6 of pleon	Scarcely apparent ...	Not apparent	Not apparent	Slight	Well marked.
Appendages— Second maxillae ...	Outer lobes as long as the base	Outer lobes longer than the base	Outer lobes much shorter than the base	Outer lobes not as short as in Phreatoicus but shorter than base	Outer lobes as long as base.
First appendage of peraeon (male)	Palm convex proximally, straight distally, dactyl much shorter than propod	Palm slightly concave, set with spines and bearing a stout tooth, dactyl shorter than propod	Palm convex, dactyl slightly shorter than propod	Palm convex proximally, concave distally, dactyl as long as propod	Palm almost entirely concave, dactyl curved, almost as long as propod.
Fourth appendage of peraeon	Shorter than other peraeopods but not sexually differentiated	Not sexually differentiated	Shorter than other peraeopods, sexually differentiated	Shorter than other peraeopods, sexually differentiated	Not shorter than other peraeopods nor sexually differentiated.
Pleura	Slightly produced ...	As in Phreatoicus ...	Produced to a depth almost equal to that of related segments	Scarcely produced ...	As in Hyperoedesipus.
Pleopods	Exposed. Epipodites on 3, 4, 5. Plumose setae few, penial filament without setae	Hidden by pleura. Epipodites on 3, 4, 5. No plumose setae. Penial filament without setae	Hidden by pleura. Epipodites on 3, 4, 5. Plumose setae present. Penial filament with 4 — 5 short setae	Exposed. No Epipodites. Plumose setae abundant. Penial filament with two long setae	Exposed. No epipodites. No plumose setae. Penial filament without setae.
Uropods	Peduncle $\frac{1}{2}$ length and $\frac{1}{3}$ depth of tail-piece. Rami shorter than peduncle.	Not projecting beyond tailpiece	Peduncle $\frac{2}{3}$ length and $\frac{1}{4}$ depth of tail-piece. Rami shorter than peduncle	Peduncle slightly greater than $\frac{1}{2}$ length and approximately $\frac{1}{3}$ depth of tail-piece. Rami shorter than peduncle	Peduncle almost $\frac{1}{3}$ length and $\frac{1}{2}$ depth of tail-piece. Rami longer than peduncle.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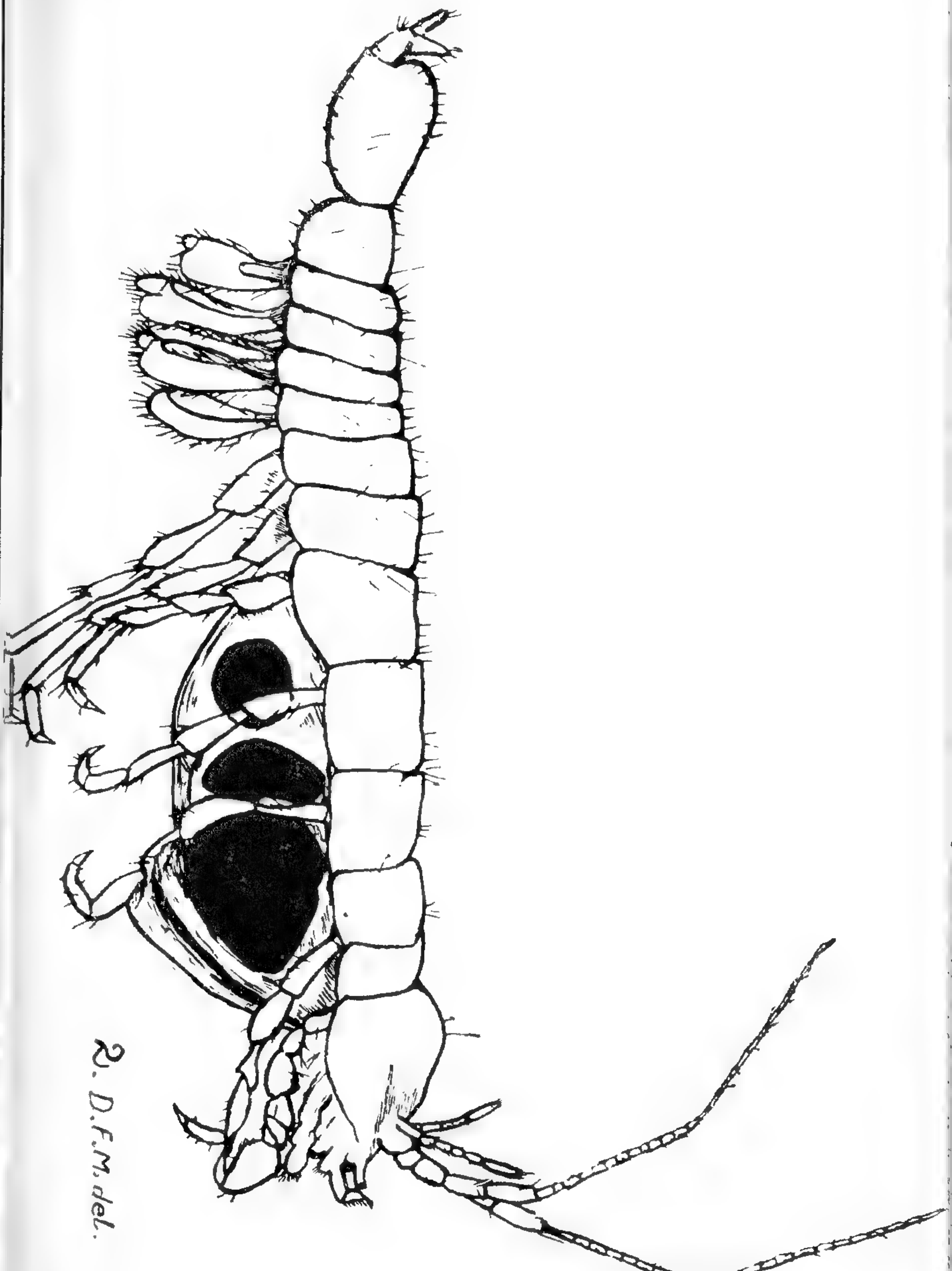
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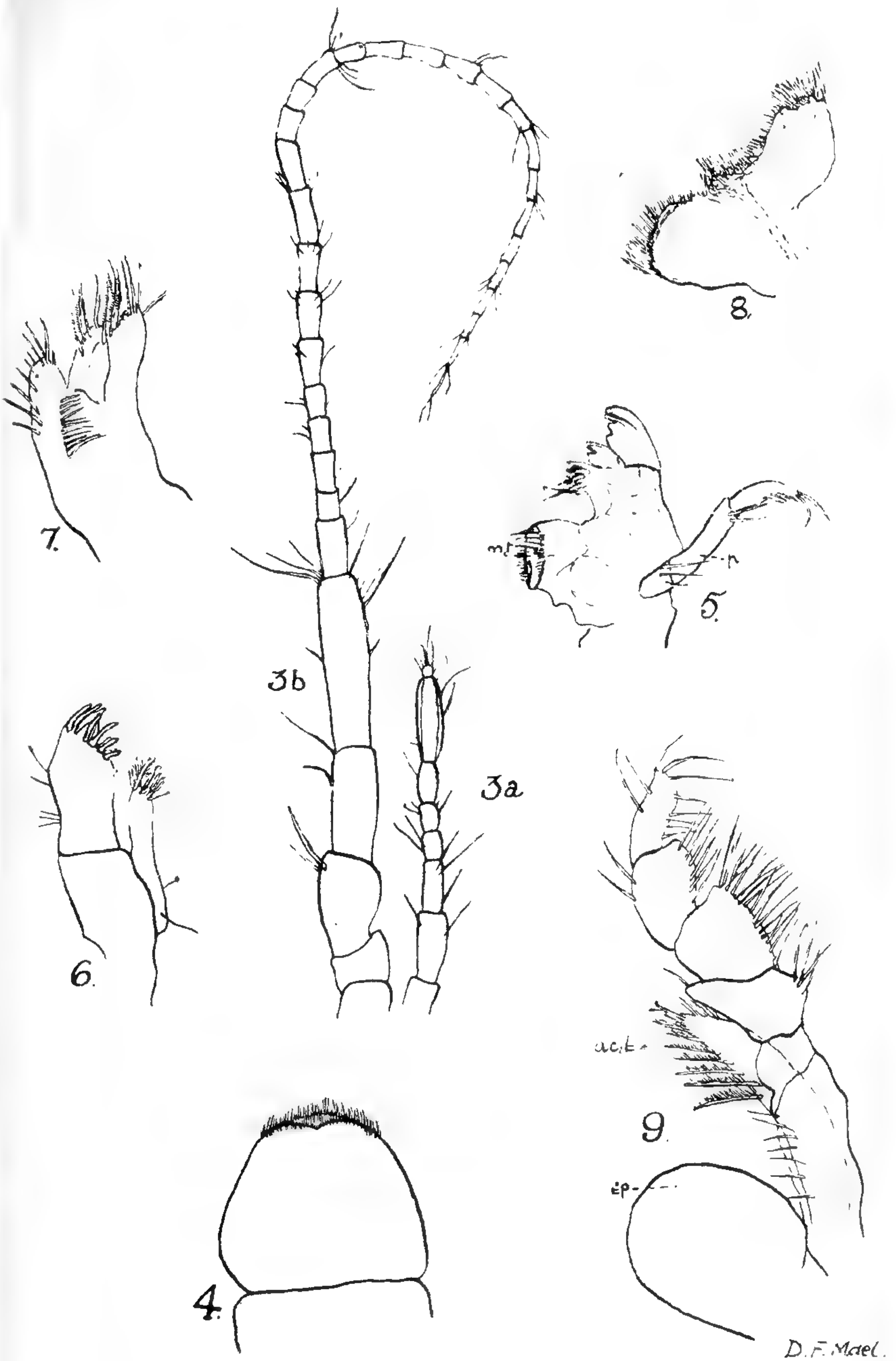
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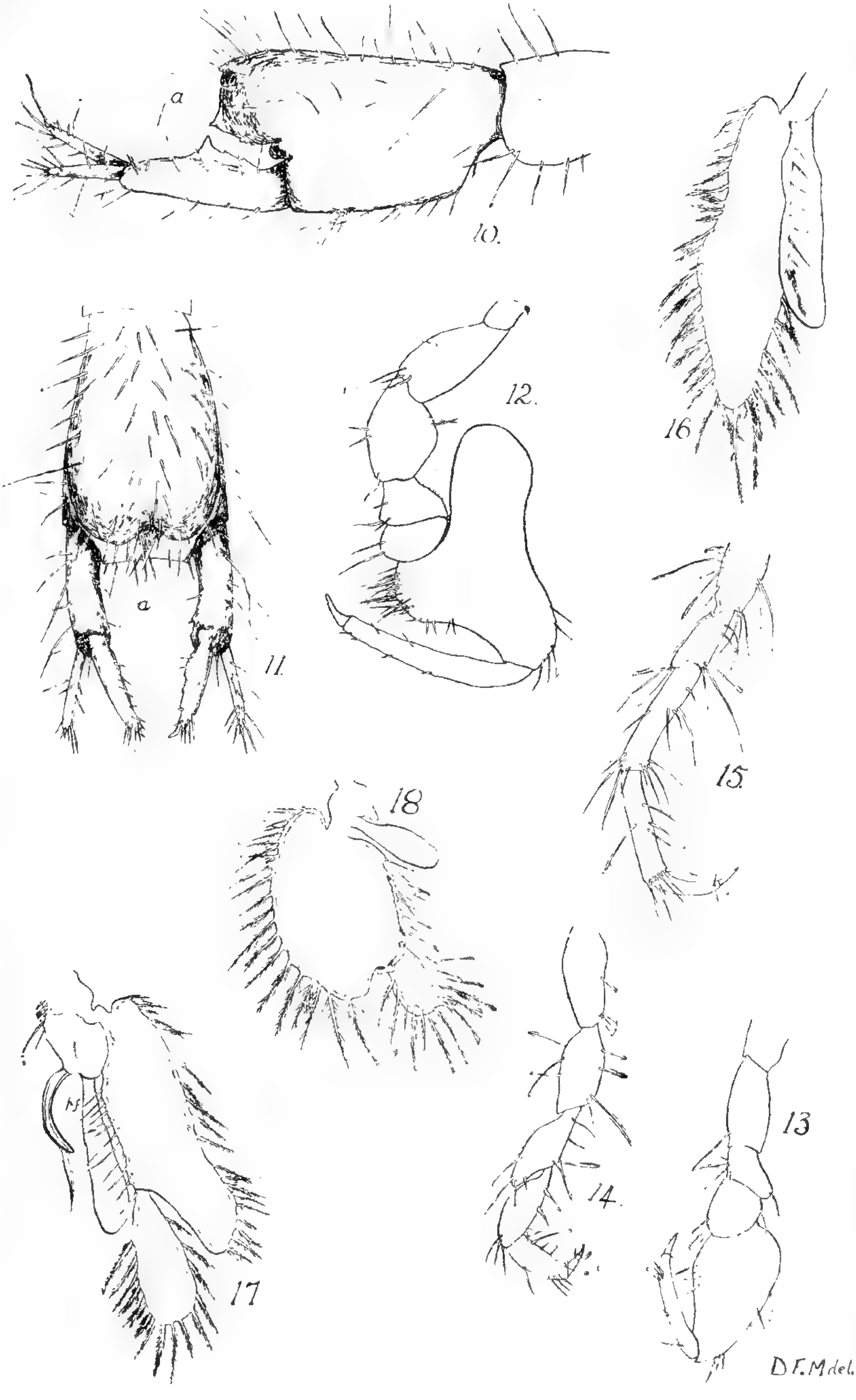
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Increase of Salt in Soil and Streams following the Destruction of the Native Vegetation, by W. E. Wood, Inspecting Engineer, Railway Department.

(*Read* November 13, 1923. *Issued* March 1, 1924.)

For many years I have been interested in the fact that in certain districts in the southern portion of Australia where destruction of the native vegetation has taken place rapidly, there has followed a very noticeable increase in salinity in the streams draining that area.

I first noticed this over 30 years ago in Yorke's Peninsula, South Australia. Watercourses were rare but there were many depressions where soakage from higher ground gathered during the winter. In some of these depressions, gardens and orchards were planted with good results for a while, but in a few years, owing to a great increase of salt in the soil, many of them became quite useless and had to be abandoned.

Again, some years later, about 1897, in the Northam-Toodyay district, I heard it suggested that destruction of the native vegetation turned the water in the creeks salt; and about 1904 I thought that I could see evidence of increase of salinity in the Goomalling Agricultural Area.

By 1905 a number of Railway water supplies had become too salt for economical use in boilers, and various officers of the Department, particularly Mr. Bleazby, Civil Engineer, and Mr. Limb, Analyst and Chemist, gave a lot of time and thought to the problem.

Their first investigation of note was at Cranbrook, on the Great Southern Railway, long. 117° 35′ E., lat. 34° 17′ S. This supply was constructed about 1888 and consisted of an excavated tank supplied by drains from a catchment the centre of which was about two miles distant. During the early years of its life the catchment was all, or nearly all, unimproved land; but in later years the southern side of the area was ringbarked and, later on, cultivated.

About 14 years after construction the water began to get noticeably salt and to give trouble in locomotive boilers. By December, 1904, the salt-content had reached 63.5 grs. per gallon. In 1908 the catchment was tested to find the source of the bad water, and it was located on the southern side where cultivation had been in progress for a few years at that date. On the southern side of the catchment the salts in the water running in the drains in winter ranged from 30 to 73 grains per gallon; but, on the northern side, the drains

which collected water from unimproved land, supplied water to the dam with a salt-content of about 7 grs. only. New cut-off drains were then constructed to divert the southern drainage from the dam, excepting when the flow was very strong, following very heavy rains. This was quite successful, and when the reservoir was filled again the salt-content was less than 7 grs. per gallon. It has remained good since that time, and about four years ago a second tank was constructed alongside the first and the salt difficulties appear to be overcome.

Another reservoir on the Great Southern Railway where salt trouble developed is at Yornaning, long. 117° 10′ E., lat. 32° 43′ S. This supply, also, was constructed about 1888 on the south branch of the Hotham River. Settlement progressed rapidly in this district between the years 1896 and 1904, and the water, which had been particularly good in the early years of the supply increased in salt-content to 60 grs. per gallon in 1909—21 years after the reservoir was built. In May, 1910, it had reached 94 grs., and it was found on investigation that the Hotham was salt for several miles above this place. Fortunately, it was found also that two small creeks feeding the river nearby were still good; so the river water was diverted from the reservoir and the two creeks relied on to supply sufficient for railway requirements, the catchments of these creeks being acquired and the timber growing thereon protected from destruction. The result was quite successful. Following is a record of the salinity of the reservoir from 1910 to 1918:—

August 29,	1910	...	3·28	grs. per gallon.
November 11,	1911	...	16·38	,, ,,
August 5,	1913	...	4·1	,, ,,
March 1,	1916	...	6·97	,, ,,
August 28,	1916	...	5·33	,, ,,
March 3,	1917	...	9·02	,, ,,
August 31,	1917	...	4·1	,, ,,
February 25,	1918	...	4·92	,, ,,
August 28,	1918	...	4·1	,, ,,

Other supplies on the Great Southern Railway that were satisfactory for a time, but deteriorated in later years, following the opening up for settlement and cultivation of the areas drained are—Wagin (since corrected to a large extent by diverting the run-off from light rainfalls and the water that soaks out of the ground after the heavy rains have stopped) and Tambellup, where the supply from Gordon River had to be abandoned, as the salt water could not be economically diverted.

Another noteworthy example of a large stream becoming salt is the Blackwood River at Bridgetown, long. 116° 8′ E., lat. 33° 55′ S. I have not been able to trace its salt-content before 1904, although it had been in use for railway boilers for about seven years at that date.

The following records of tests have been kindly supplied by Mr. Limb; and, to those people who know the history of the agricultural developments in the Arthur River District—the water from the Arthur River joins the Blackwood River above Bridgetown—it will be easily recognised how the increase of salt has followed within a very few years upon the rapid extension of cultivated land in the agricultural portion of the catchment.

BLACKWOOD RIVER RAILWAY SUPPLY, BRIDGETOWN.

Date.	Salt.	Total Solids.	Hardness.		Remarks.
			Total.	Temporary.	
	Grs. per gallon.	Grs. per gallon.	Grs. per gallon.	Grs. per gallon.	
January 26, 1904 ...	10·95	18·94	7·0	...	First test of supply.
October 27, 1908 ...	19·00	32·9	9·4	2·6	
December 28, 1910	26·01	45·84	14·05	6·95	
March 10, 1911 ...	38·1	58·35	20·4	11·00	
May 30, 1911 ...	54·9	80·00	21·17	9·6	
July 20, 1911 ...	73·8	105 00	27·3	9·2	
August 18, 1911 ...	63·96	83·00	15·4	3·85	
September, 1911 ...	56·17	77·00	17·32	7·87	
December 12, 1911...	84·05	105·00	23·9	6·4	
April 22, 1912 ...	100·00	130·00	25·3	10·1	1912 rains below normal.
July 18, 1912 ...	105·78	120·00	26·77	8·57	
September 2, 1912 ...	84·46	98·00	21·00	8·05	
December 23, 1912...	76·26	90·00	21·7	6·12	
July 31, 1913 ...	35·2	45·00	11·9	2·45	
August 16, 1913 ...	9·02	12·00	2·27	1·57	Probable heavy fall of rain.
November 17, 1913	36·9	46·00	14·17	5·25	1914 rainfall much below the average.
January 10, 1914 ...	46·74	63·00	18·2	6·6	
April 24, 1914 ...	68·06	72·00	23·97	9·02	
September 10, 1914	88·1	105·00	25·0	7·1	
October 19, 1914 ...	103·3	120·00	29·22	6·82	
February, 1915 ...	94·3	115·00	28·87	8·57	
August 20, 1915 ...	80·7	95·00	25·9	2·97	
November 26, 1915	53·3	65·00	15·75	4·72	
September 18, 1916	37·31	50·00	10·76	3·58	
March 30, 1917 ...	70·52	90·00	23·62	7·87	
September, 1917 ...	21·32	26·00	5·42	2·8	After winter of record heavy rain. Supply now abandoned for new supply.

In 1913 I spent a few months on water-supply surveys in the South-Western District and soon became convinced that a number of small watercourses that had contained fresh water a few years earlier were becoming salt; and that quite an appreciable amount of rich valley land along the edges of some of the streams was also being ruined by the salt deposited when the water dried up.

In 1916 I was given a further period on somewhat similar work and continued at it for five years. During that time I investigated many locomotive boiler supplies that had become too salt for further use, or threatened to become so soon. I took the opportunity to revisit Formby, long. 118° E., lat. 34° S., where there was a small dam across a creek about one-quarter of a mile below the siding. This had shown strong evidence of increasing salinity when I was there in 1913. I had been told that the water was perfectly fresh in 1911 and 1912 when the railway was being constructed, and in August, 1913, it contained water having 40 grs. of salt per gallon. When I next tested it in November, 1916, the dam was full, but the salt had increased to about 2,000 grs. per gallon. It was said that the catchment had been cleared of nearly all native vegetation very quickly between the years of 1909 and 1913, and the new growth of saline vegetation growing in the creek and on the low-lying ground nearby was noticed by me in 1913.

It seems fairly safe to state that nearly all the districts on the inland side of the Darling Range, and lying close thereto, show some evidence of somewhat similar happenings where the native vegetation is destroyed in large quantity. The same thing applies to a certain extent in other districts where there is a good winter rainfall, but in the Darling Range, and on the upper reaches of most of the streams entering the Indian Ocean in the South-Western District, the destruction of timber and shrubs has not reached the extent that it has in the purely agricultural districts, and possibly can be prevented if large areas are protected in time.

There are now very few rivers, crossed by the railway, that contain water fresh enough at all seasons of the year to be classed as good boiler water. Water is still used from the Murray River at Pinjarra, and the Preston River at Boyanup and Donnybrook; but the increase of salt is becoming noticeable, although the pencentage of the area drained by these rivers and upon which the native vegetation has been destroyed is not great. Probably, if the destrction proceeds unchecked these streams also will have to be abandoned as sources of boiler water.

The Murray River water at Pinjarra, long. 115° 59′ E., lat. 32° 30′ S., is always worst just after the first rains, which, if heavy and

continuous, ultimately reduce the salt-content to 20-30 grs.; if the rains are light the process is a slow one. This year the analyses, March to July, were as follows:—

14–3–23	...	29·5	grs. of	salt per	gallon.
18–6–23	...	96	,,	,,	,,
25–6–23	...	40	,,	,,	,,
2–7–23	...	20·5	,,	,,	,,
9–7–23	...	19·7	,,	,,	,,

Although it is generally recognised that our streams increase in salinity after the native vegetation has been destroyed, I am not aware that anyone has explained the increase of salinity or the origin of the salt which causes the salinity, and I submit the following theory for discussion:—

Over a very large portion of the South-West District, more particularly that area comprised in the Darling Ranges and the wandoo, jamwood, and white gum country immediately adjacent thereto, a typical section of the ground from the surface down to the underlying rock could be described approximately as follows:—

(a) Sandy soil.

(b) Sandy clay.

(c) Very dense clay and sand cemented together, and nearly impervious. This is commonly named "hardpan."

(d) Softer ground—often thoroughly decomposed rock *in situ.*

(e) Partly decomposed rock merging into solid rock below.

Before the native bush is destroyed, the ground is covered with vegetation, composed of large timber, of smaller and larger shrubs and of wild grasses, all growing together. All have their roots in (a) and to a less extent in (b); a few penetrate a short distance into (c). The main roots of the large trees pass through (c), and in (d) find moisture to carry the trees through the long dry summer without wilting.

While the bush remains in its virgin state, or nearly so, rain falling on the catchment area is partly absorbed by the soft layer (a), and, if the rain is long continued, some soaks into layer (b).

If the rain is very heavy, a lot runs off along the surface to the nearest watercourse to be borne rapidly towards the sea. The water that enters (a) is held by the network of small roots, and as much as is required is absorbed and stored by the vegetation. Some of the water enters (c), chiefly by following down the tap-roots of dead and decaying trees, and this is the water usually found when sinking wells; it is stored between the two almost impervious layers (c) and (e).

It is of special importance, for further consideration of the subject, that the difference of quality of water in the upper layers (a) and (b) and that in (d) be noted here. Before interference with the native vegetation the upper water is almost as fresh as rain, but in layer (d) it usually ranges from brackish to salt—in many cases too salt for stock.

The accompanying diagram shows a typical hillside section:—

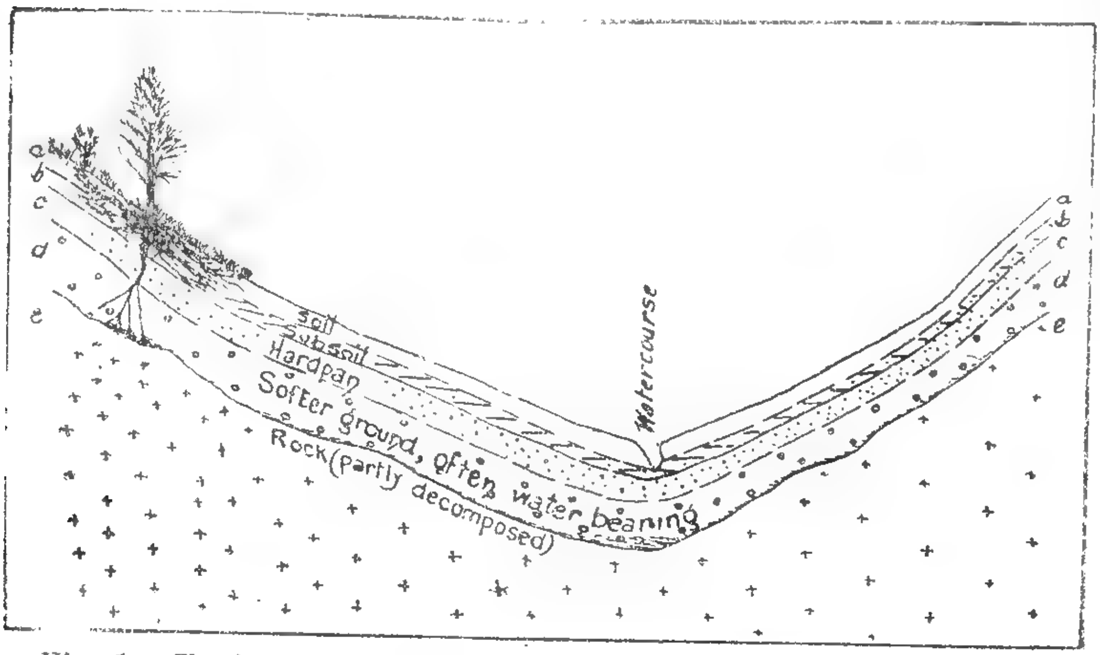

Fig. 1.—Typical cross-section of a valley. A taproot has penetrated the "hardpan" to obtain water.

It is evident that the layer (d) containing brackish water is, where on the hillside, higher than the ground surface near the watercourse. If anything happens to swell the volume of water in layer (d) on the hillside it will tend to raise the water-table in (d) near the watercourse. My suggestion is that the killing of large timber on the hillsides, followed by decay of the roots, permits more water to enter (d) than formerly. Moreover, if the surface is cultivated, the soil acts as a sponge to hold more water, which in turn drains into the underground channel (d). It can be assumed then that more water will drain into (d) than can percolate away to the coast with-

out raising the water-table. As a consequence of this, water will, if increased greatly, rise to the semi-impervious layer (c), and if that has also been rendered pervious by decayed root holes near the water-course, the underground water will rise through it, and perhaps to the surface, bringing its salts with it. When the rainy season is over the water will gradually dry up, leaving evidence of its salinity on the surface in a salty incrustation on the low-lying ground.

More than one explanation of the greater salinity of water in layer (d) than in the upper layers has been advanced. It has been suggested that the decomposition of the country rock has released the salts; but these salts are mainly chlorides, and, so far as I have been able to ascertain, there is not sufficient chlorine in the rocks to account for the salts in the water. Neither is there evidence of saline beds such as might be expected if the sea had been over the land in recent geological times, and, when receding, had left salt stored in the upper layers of the soil. In any case this explanation does not seem satisfactory, for rinsing by rain-water, continued for the long time during which this part of the State has remained under the same physiographic conditions, would have washed nearly all the salt out of the higher levels and concentrated it lower down if it had not carried it away to sea. But I have found places where the concentration was greater at the higher levels than at the lower. One of these is a few miles from Narrogin, about long. 117° 15′ E., lat. 33° S. At this place a ridge runs eastward from the Darling Range, and forms portion of the divide between the Avon, the Hotham, and the Arthur Rivers. The ridge is nearly denuded of indigenous vegetation now, and the creeks flow strongly from near the summit in winter. I tested many of the streams in August, 1919, and found not one of them suitable for water supply purposes, owing to their high salt-content; but although they range from 46 to over 400 grs. in the upper levels, they were markedly fresher two or three miles lower down, where 25 grs. appeared to be the average.

The occurrence near Narrogin, coupled with another near Albany, seemed to me to support a theory I had formed some years previously that, most of the salt, at least in the South-Western Division of Western Australia, is air-borne, and that salt is still being brought in from the sea in material quantity, and is either deposited in rain, or as a dry powder, or in dew, chiefly in summer.

The salt would be derived from very fine spray formed by the strong breezes which lash the tops of the waves into spindrift at any season of the year; but in summer, usually under a cloudless sky, the spray would evaporate quickly and the fine residue of salt would remain in suspension while the wind continued strong. The outline of the particle of salt would probably be irregular, with a

very large surface compared to its actual weight, and it is not hard to imagine the transportation of such particles for a long distance under the described circumstances.

These winds blow for hours, usually starting about noon of most days in summer, from the West and South-West, and travelling far inland before they fade and lose their strength. They are known locally as the Fremantle, Dongarra, Albany, Esperance, etc., "Doctors," according to the part of the coast whence they come.

So far as the salt in rain is concerned, it is not so very exceptional to find 3 grs. of salt per gallon in rain falling on the western slopes of the Darling Range, and during a very strong gale, that had lasted four days, at the end of June, 1917, I tested rain and hail at Donnybrook, long. 115° 40′ E., lat. 33° 38′ S., distant about 20 miles from the Indian Ocean, and found them to contain 8 grs. of alkaline chloride. The salt-content was only 4 grs. in rain that fell about two hours later. I had hoped to go further into the matter with Mr. Curlewis, of the Meteorological Bureau, and Mr. Limb, the Railway Department's Analyst, but so far neither time nor funds has been available.

As further evidence of the amount of salt borne inland yearly, I would mention an occurrence at Mullewa this year. Mullewa is situated near the north end of the South-Western Division of Western Australia in long. 115° 30′ E., lat. 218° 30′ S. It is about 60 miles from the coast, and there are two railway tank dams there for locomotive purposes, one dam lined with concrete, the other unlined. It was a very dry season last year, and no water entered the dams from the first week in August, 1922, to the second in March, 1923. The catchments join near the town and the dams are about half a mile apart. The catchment of the unlined dam was kept free from stock, being fenced, and is covered almost completely with green timber. The surface is very impervious, being chiefly hard clay and, in some places, a very hard rock, whose original character has been much altered by the processes of weathering characteristic of these regions. There is very little soft ground for water to soak into readily. The catchment for the lined dam is somewhat similar but is subject to pollution by wandering stock and people living on it. In March of this year a local thunderstorm crossed the catchment of the unlined dam and put about 200,000 gallons of water into the dam, which is sunk in hard clay and decomposed rock (probably granite). The water was tested and found to contain 180 grs. of salt per gallon. As the normal salt-content of both dams is about 7 grs., I had water from the masonry silt pit tested, in case the excessive salt was a soakage into the unlined dam. The silt pit water contained 176 grs. This water was then all pumped to waste.

As the storm had not set water running on the other catchment, water from the lined dam could not be tested, but I made arrangements to get tests of water from both catchments should there be a suitable rain, and, a few weeks later, a good thunderstorm passed over and put water in both dams. 600,000 gallons were impounded in the lined dam, which had not benefited by the previous rain, and the salt-content was 33½ grs. per gallon and 19.68 grs. in the silt pit of that dam, but in the silt pit of the dam of the previously washed catchment the salt was only 2.87 grs. per gallon, thus a considerable salt-content was obtained from the catchment which had not been washed by the previous rain, and a small salt-content from the one which had. There are no salt lakes of large extent near Mullewa and most of the country is still covered with green timber of small size.

If the Mullewa records can be accepted as evidence of a salt film of material thickness being deposited over the South-Western District of Western Australia during the summer months, they will assist in explaining the phenomena of salinity in the Murray River at Pinjarra, over 300 miles farther south, where it is found (*see* table on a previous page) that the river water is salter after the first rains following the dry season than during the height of the dry season.

DISCUSSION.

Mr. A. Montgomery congratulated Mr. Wood on the number of very valuable records of instances of increased salinity which had come within his personal professional experience. His suggestion that the death and decay of large roots which penetrate the subsoil deeply, facilitated the passage of surface waters through the hardpan seemed particularly worthy of attention, and the inference that the water-table would be raised in the lower-lying ground seemed sound. The manifest remedy for salinification of low-lying ground lay in good drainage, which would drain off the rising saline waters well below the surface of the ground and not allow them to rise high enough to injure the crops.

The subject dealt with by Mr. Wood had an important bearing on the physiography and recent geological history of the State. He (Mr. Montgomery) had paid a good deal of attention to the subject and had (Jour. Roy. Soc. W.A., Vol. II., p. 59) ascribed the exces-

sive and widespread salinity of the part of the State lying south of about lat. 29° S. to a recent submergence followed by elevation into its present position.

Regarding Mr. Wood's opinion that soil salinity is due to particles of salt borne by the wind from the surface of the sea, the presence of salt in atmospheric dust and in rain and dew is recognised, but the amount borne inland must, he thought, be similar all over the world, for clouds formed by condensation of vapour from the sea are often borne far inland, and doubtless the fine saline dust can be carried just as far by the same air currents. Hence all arid regions should accumulate sea-salt in their soils, for none are beyond the reach of winds circulating both over land and sea. However, there are many arid regions in which salts other than sodium chloride predominate. Even in Australia the occurrence of saline areas is distinctly regional and not universal.

It was to be noted that the amount of saline matter in the air has not necessarily any relation to the amount of water evaporated, since the salt-dust in the air is derived from particles of spray carried by wind into the air and there evaporated. Most of the spray falls back into the sea, and only a small percentage is evaporated and contributes salt-dust which may be carried inland by the wind.

Mr. Montgomery considered that wind-action on the saline surfaces of the many salt "lakes" of Western Australia must contribute very largely to salt-dust in the air, which must be constantly falling and forming a layer on the surface of the ground which would dissolve when the first shower of rain fell on it. He would ascribe to such terrigenous salt-dust the sudden isrcease in salinity of the Mullewa dams described by Mr. Wood.

Mr. Montgomery stated that numerous wells throughout the more saline districts show that fresh water is near the surface, and that, if the well is deepened, we reach first brackish then salt water. He thought there could be no doubt that this is due to the rainfall being fresh water, which sinks into the soil and forms a layer of lighter fresh water upon the heavier saline waters accumulated below. In such circumstances the mixture of the fresh and salt water would progress very slowly. A well known case was that of wells near the seashore, where rain-water sinks through sand and accumulates in a subsoil pool, displacing the salt water, a higher column of the lighter fresh water balancing a lower one of the heavier salt water. He considered that our Goldfields "soaks" near granite rocks are another instance of the same action.

The salinification of cultivated lands on removal of the native vegetation he believed most probably to be due to quicker evapora-

tion from the bared soil. When the cover of natural vegetation and the shade of trees are removed, evaporation is much more rapid, and capillary attraction brings up through the soil the more saline waters lying below the surface, causing a concentration of salt from these by evaporation.

That the salt is in the soil and emanating from it, and not being brought down from atmospheric salt-dust, seemed to him to be fairly well proved by the experience of the Mundaring dam, where it is necessary from time to time to run out to waste a quantity of somewhat salt water from the bottom of the dam, where it accumulates. The salt water once thoroughly mixed with fresh cannot separate again, and the salt water layer on the bottom must, in his opinion, come from the earth below the dam and not from the streams filling it. Doubtless this saline accumulation would disappear in course of time.

Dr. E. S. Simpson congratulated Mr. Wood on the assemblage of observations, extending over many years, which he had put together. He agreed that the salts the author dealt with had not come from the weathering of the rocks, if they had, then carbonates and sulphates would predominate. He thought that in this, as in many other phenomena, several causes had contributed to the final result. He had watched at Yallingup the drifting inland of mists composed of finely comminuted spray from the sea, and noticed the strong salinity of ground waters within a mile or two of the shore in that neighbourhood, but one only had to go four or five miles inland to find fresh ground-waters. Thus, he considered, that the wind-borne salt was not adequate to account for the widespread occurrence, south of about lat. 20°. S., of saline ground-water in the interior of the State. Determinations of air-borne ocean salts made some years ago in Cumberland pointed in the same direction. He believed that the salt water was oceanic in origin and dated from the Cainozoic submergence of the southern part of the State. He thought Mr. Wood's explanation of increase of salinity was sound, but drew attention to some other contributory factors, namely, the inevitable increase in salinity which must take place, under the climatic conditions obtaining in Western Australia, in every dam which is not regularly and completely emptied; the increase in surface salinity which must follow on the removal of vegetation which by its root-absorption would check the upward capillary movement of the deeper water with its dissolved salts; and the fact that in seasons of excessive rainfall far inland the west-flowing rivers of the South-West Division receive some overflow water from the lakes (salinas) of the inland area, the sub-surface water of which is saturated with salt, gypsum, magnesium sulphate, and magnesium chloride.

Mr. J. M. Limb, Chemist to the Railway Department, was invited by the President to contribute to the discussion, and remarked that there was a great accumulation of data in possession of the Railway Department, which, if properly arranged, might throw considerable light on the subject under review. He gave instances of the variation of salinity of a number of water supplies which he had personally investigated; those specially mentioned being at Cranbrook, Yornaning and Wagin. In each instance it had been proved that the variation in salinity was not due to any fault in the dam, but to contamination from some part of the watershed.

In the case of the two first-mentioned, the contaminated waters could be diverted, but in the case of Wagin, where the source of contamination was in the centre of the catchment, and could not be isolated, the permanent low wall weir was the only method of obtaining suitable water after heavy rains.

He had found by experience that small reservoirs could not be well compared with very large ones, and that Mr. Montgomery's contention regarding the high salinity of the bottom layers in Mundaring water was not supported by the evidence in his possession. He had found that where the main intake of a reservoir was far removed from the wall, there was only slow diffusion, and data appeared to indicate that at Mundaring the more saline water following the lighter rains did not reach the wall until the subsequent heavy rainy season. This was evidenced by sharp increase in salinity prior to very considerable and rapid improvement. The following figures would demonstrate the point.

Year	Date	Salt in grains pr gallon.
1915	May average ...	30·2
	June average ...	30·2
	July average ...	32·4
	August 4th ...	31·15
	August 5th ...	29·5
	August 6th ...	27·0
	August 9th ...	26·0
	August 12th ...	12·3
	August 13th ...	10·6
1917	May average ...	22·4
	June 12th	22·9
	June 22nd	24·2
	June 26th	24·6
	June 27th	13·8
	June 28th	11·5
	July 25th	7·8

It had further been found that when the sluice was open, the water in the creek was almost identical with the water supplied by means of the various mains, and improved at the same time as the water in the mains improved when better water reached the wall.

Confirmation of this was also found in the Chidlows reservoir water supply, which contains 117 million gallons. The depth of water at the wall being 29 feet. Even when the rains were light and the streams very saline, the difference between top and bottom water had never exceeded 2.0 grains per gallon at the wall. He felt that the subject was such that it was impossible to cover the field adequately or consider fully the data available in the time allotted.

Mr. W. Catton Grasby congratulated Mr. Wood on having made a notable contribution to a difficult and very interesting problem. He thought, however, that there was not much passage of water from the surface through the hardpans, and, where the section applied, this water did not again pass upward through the hardpan in order to reach the surface on lower ground. He (Mr. Grasby) considered that the saline water which caused gullies to become salt was carried through the soil and subsoil by the winter rains and was carried down the slopes over the hardpan. He further noted that Mr. Wood's diagrammatic section did not represent the conditions of the best forest land in the wheat belt, although it certainly was typical of the localities of the railway tanks referred to.

The best wheat lands were more or less wide, almost flat stretches of country separated by higher undulating moor or heath and scrub lands, commonly but wrongly called "sandplain." The valleys were covered with forests, chiefly Salmon Gum (*Eucalyptus salmonophloia*), Morrell (*E. longicornis*), Gimlet (*E. salubris*), and York Gum (*E. loxophleba*).

Fresh water soaks and shallow wells were often found on the borders of the moorlands or "sandplains," but in the richer, deeper, "made" soil of the timber country, while it was in many places easy to get water in wells, it was almost invariably salt.

Mr. Wood, in reply, remarked that his paper dealt only with the South-Western District, more particularly the Darling Range and the country immediately adjacent to it, and he hardly expected, as Dr. Simpson and Mr. Montgomery seemed to think he did, that his conclusions would be equally applicable to every part of the State. Still, he believed that the boundary between that part of the State in which ground-water was salt and that in which it was potable, corresponded approximately to the boundary between areas of winter and of summer rainfall, and that all the country alike became covered during dry weather with a skin of wind-borne salt particles. In the areas of summer thunderstorms, however, the torrential rain washed the salt down into the watercourses, so preventing its accumulation in the soil. He referred to the occurrences at Mullewa, already detailed, as supporting this view.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

Contributions to the Fauna of Western Australia, No. 4. A Freshwater Isopod Phreatoicus palustris, n. sp.

By L. GLAUERT, F.G.S.

(*Read* March 13, 1923, and withdrawn for amplification. Re-submitted December, 1923. *Issued* March 1, 1924).

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Thi crustacean was first discovered in February, 1923, by Mr. K. Shea d, a monitor of the Perth Boys' School, in Smith's Lake, North Perth, whilst collecting specimens for he Biological Laboratory of the school. Subsequently a number of the animals were brought to the Museum alive, where several of them were kept under observation in a glass vessel, on the bottom of which a quantity of mud had been placed. The mud was covered with from three to four inches of water to which rain-water was added from time to time in order to balance loss by evaporation.

The animals were evidently quite at home, for several of them paired, and the noticed mortality among them was very slight. When pairing the male seized the female with his powerfully developed gnathopods making no use at all of the fourth pair of peracopods which, therefore, do not show the modifications noted in *P. australis*, *P. capensis* and *P. shephardi*.

Ecdysis is rarely completed in one action, I have often seen animals with the old "skin" shed from the pleon and telson and have but on one occasion observed the complete "skin" lying on the muddy floor, and then not in one piece.

The animals are fairly active and exceedingly quick at burrowing into the soft muddy bottom, but at times they will, when disturbed, lie motionless, evidently relying upon heir coloration for protection. They spend much of the day in the soft muddy bed of their home, and when not burrowing, prefer dark or shady corners. Their food seems to consist of animal and vegetable matter, and they make most efficient scavengers.

I have reasons to believe that they are most active at nighttime.

Sub order PHREATOICIDEA, Stebbing, 1893.*

Family PHREATOICIDAE, Chilton, 1891.

Body subcylindrical, more or less laterally compressed. Mandibles with a well developed appendage. Legs distinctly divided into an anterior series of four, and a posterior series of three. Pleopoda broad and foliaceous and branchial in function, but not protected by an operculum. Pleon large of six distinct segments. Uropoda styliform.

* *See* list of references at the end of this paper.

Genus PHREATOICUS, Chilton, 1882 and 1894.

Body long, subcylindrical, laterally compressed (seen chiefly in the pleon). Upper antenna short, lower long, with flagellum. Mandible with an appendage. First pair of legs subchelate in both sexes, but larger in the male than in the female, others simple (the fourth pair in the male slightly modified so as to be almost subchelate). Legs divided into an anterior series of four, and a posterior series of three. Pleon long, of six distinct segments, last joined to the telson. Uropoda biramous styliform. Telson large, subconical.

The genus *Phreatoicus* was established by Chilton in 1882 to include a blind Isopod Crustacean, found in wells near Canterbury, New Zealand, to which the name *Phreatoicus typicus* was given.

In 1891 the same author described a species, *P. australis*, discovered by the late Richard Helms on Mt. Kosciusko, at an altitude of 5,700ft., this species possesses well developed eyes, it has also been found in Tasmania and Victoria. Another blind form, *P. assimilis*, from wells near Canterbury, N.Z., was described by Chilton in 1894. A second species from Tasmania, *P. tasmaniae*, was founded by G. M. Thomson in the same year, and in it was included a young specimen which he had in 1892 regarded as *P. australis*.

In 1900 O. A. Sayce described a blind species from the Dividing Range, Victoria, at an altitude of 2,000ft., as *P. shephardi*, this form has subsequently been collected at Barrington Tops, N.S.W., in subalpine surroundings, 5,000ft., by C. Hedley (Chilton, 1916). A third blind New Zealand species *P. kirkii* was recorded from a freshwater lagoon in 1906, with a variety *P. kirkii dunedinensis*, from streams near Dunedin, N.Z.

In 1909 G. Smith described two new Tasmanian species from the Great Lake, altitude 3,000ft., *P. spinosus* and *P. brevicaudatus*, the former of which is considered by Barnard (1914), as possibly only a larger form of Thomson's *P. tasmaniae*, an opinion shared by Chilton (1917—p. 385). A species found "near the reservoir on the top of Table Mountain . . . . . . under the moss growing on the stones in the bed of a swiftly running stream . . . . . . at an altitude of about 3,000ft." was described as *P. capensis* by Barnard in 1914.

The Triassic Wianamatta Shale of St. Peter's Brickworks, Newtown, Sydney, N.S.W., has yielded a number of fossil crustaceans which were described by Chilton in 1917 under the name of *P. wianamattensis* as "closely similar to existing Australian species such as *P. australis* and *P. shephardi*" (Chilton 1917—p. 24).

Finally, in 1922 Chilton dealt with a new species, *P. latipes* "collected in June, 1920, in artesian water from the Hergott (Marree) bore, in Central Australia, a little South of Lake Eyre." Professor F. Wood-Jones, who made the discovery has subsequently

found this species in " the mound springs near Coward, just to the Westward of Lake Eyre South." There are many of these springs which " vary greatly in salinity and temperature, but the animals are found in all the springs, from Bullakaninna to Coward, an area of some 30 miles."

PHREATOICUS PALUSTRIS—n. sp.

Specific diagnosis. Body rather slender, laterally compressed, particularly in the pleon, surface smooth,* with numerous short scattered hairs, eyes prominent, sub-circular, well developed, head about as long as the first and second peraeon segments, without a lateral groove. First antenna as long as the peduncle of the second, the second long, about three-fourths of the total length, fourth joint of the peduncle as long as the first three, fifth slender, as long as the second, third, and fourth combined. First peraeon segment fused to the head (suture distinct), shorter than the second segment, emarginate in front, straight behind, its shortest dimension in the middle line, second, third, and fourth segments sub-equal, longer than the fifth, sixth, and seventh.

Pleon long and deep, equal in length to peraeon segments 2–7, fifth segment slightly shorter than the first and second or third and fourth, posterior margin of segments 1–3 slightly concave, fourth segment with a shallow notch, fifth segment deeply notched, sixth segment fused to the telson, suture oblique, distinct laterally. Uropoda long, the basal joint reaching the end of the telson, inner ramus as long as the basal joint, with a pair of strong terminal spines, outer ramus shorter and less robust, the apex crowned with a terminal spine and several spinules and hairs. Telson convex above, with a concavity in front of the terminal projection, convex below, with numerous spines, spinules and hairs, particularly on the margins.

Length (when extended) about 15mm. The largest specimen measured was a male 17mm. long, the largest female was 15mm. Specimens 10mm. long have been noticed pairing. The breadth throughout is about 2·5mm. in a specimen 15mm. long.

Colour.—This may vary with the surroundings, but the majority seen were a dark olive brown, darkest on the dorsal region, which is separated on the peraeon and pleon from the somewhat paler margin by a light crescentic marking on each of the segments, head marbled, flattened basis and the ischium of peraeopoda five, six and seven with pale blotches, mottlings on the other joints of the legs.

On examination with a high-power lens, the coloration resolved itself into a mass of blackish stellate markings (chromatophores) on a paler background, which is identical in colour with the crescentic patches of the dorso-lateral band.

* The surface is smooth in the living animal, spirit specimens develop irregularities.

Animals kept in a vessel without a muddy bottom became distinctly paler, almost yellowish, whilst others living in or upon greyish mud soon assumed a hue more in accordance with their surroundings.

Type Locality.—Chinamen's Garden, north end of Smith's Lake, North Perth. Collected by L. Glauert and K. Sheard, February, 1923.

The species has since been found in many of the coastal swamps to the north and south of Perth, but has not yet been met with in the swamps and creeks of the Darling Ranges.

Head, almost rhomboidal in profile, slightly convex in front, with excavate anterior margin, as long as the first and second peraeon segments, eyes large, subcircular, prominent, widely separated, cheek not defined, lateral groove absent, straight below, posterior margin convex. A vertical submarginal groove in front of the eye, interorbital space slightly convex, smooth.

Peracon, first segment fused to the head, suture oblique, distinct, anterior margin excavate, posterior margin straight, inferior margin convex, anterior angle pointed, posterior angle rounded. Second, third, and fourth segments subequal broader than deep lower margin slightly excavate, anterior angles pointed, posterior angles rounded. Fifth, sixth and seventh segments, narrower and deeper than the preceding, lateral margins convex, angles rounded.

Pleon considerably longer than deep ; pleura of segments 1—5 well developed, concealing the pleopoda, their inferior margins rounded, fringed with setae ; posterior margins of segments 1—3 slightly concave, segment four with a shallow notch, fifth segment deeply notched ; fifth segment measured dorsally slightly shorter than one and two or three and four. Sixth segment fused to the telson, suture visible laterally, sixth segment and telson longer than the fifth, but shorter than the fourth and fifth.

Telson in profile gently convex above with a concavity in front of the terminal projection, lower margin distinctly convex. The terminal projection bears several apical spines and hairs, the lateral prominences are crowded with spines and hairs. Margins very spiniferous and setose.

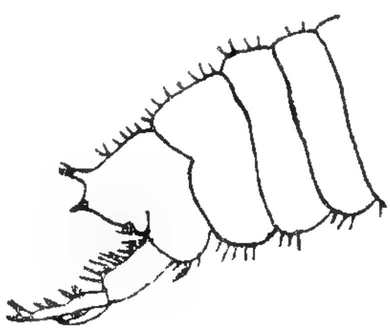

Fig. 1.—Telson, uropod and posterior segments of pleon.

First Antenna as long as the peduncle of the second, peduncle of three joints, first long, about twice as long as broad, second joint

shorter and more slender, third very slender, longer than the first. Flagellum of 8 or 9 joints, slightly tapering and not club-shaped, each joint with a terminal tuft of setae.

Second Antenna long and s'ender about three-fourths the length of the body, reaching to the third pleon segment, peduncle of five joints first two short and broad, third longer than the first and second, fourth as long as the first three, fifth slender, about as long as the second, third, and fourth : flagellum about twice as long as the peduncle, composed of from 20 to 23 joints, which become gradually more slender as they approach the apex, each joint with a terminal tuft or fringe of setae, the basal joints are fused, the next 4 or 5 short, the est elongated and ubequal.

Mouth par's.—The upper lip, lower lip, and mandibles appear to be normal, it was not possible to see the details o the last in the dissections prepared.

First maxilla.—This appendage bears two curved lobes, the outer longer and broader than the inner, its apex with about fourteen teeth in two series, the inner ones being the shorter, some of the teeth are denticulated on their inner margins. The inner lobe bears six plumose setae on its tip, and two simple spines, one at the outer, the other near the inner margin.

The first maxilla is proportionately shorter and stouter than in the other species of the genus, and the lobes are more curved.

The *second maxilla* very closely approaches that of *P. australis* the fixed inner lobe being much shorter than the two outer articulated members. The two outer lobes are convex externally, their truncated summits bearing numerous long, fine, plumose setae. The rounded tip of the fixed inner lobe bears a number of similar setae and is fringed internally to its base. As in the other species, its inner margin is concave, the outer being slightly convex.

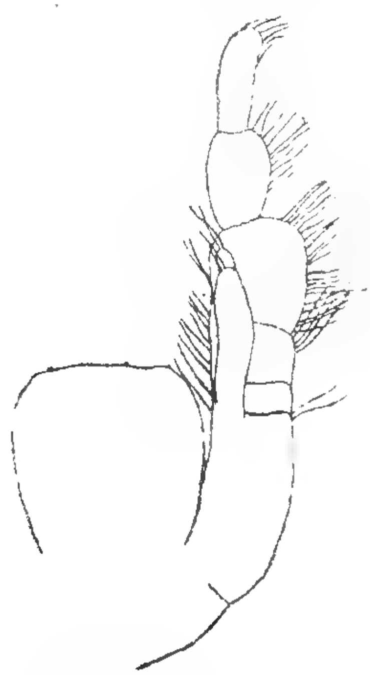

Fig. 2.—Right maxilliped from within.

The *maxillipeds*, of which the right is figured (fig. 2), have the epipodite apparently without hairs or spines along the margin.

Peraeopoda have the coxal joint short but distinct, fused to the segment; the first (gnathopod) is as figured, (fig. 3), young

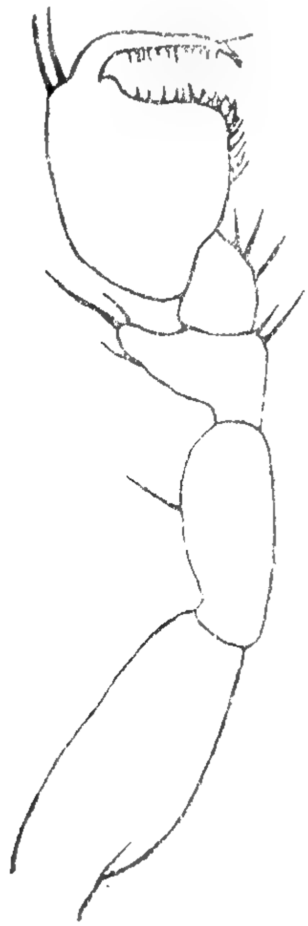

Fig. 3 "Gnathopod" of male.

males and females have the propodus similar but smaller; the second, third, and fourth peraeopoda normal, subequal and slender,

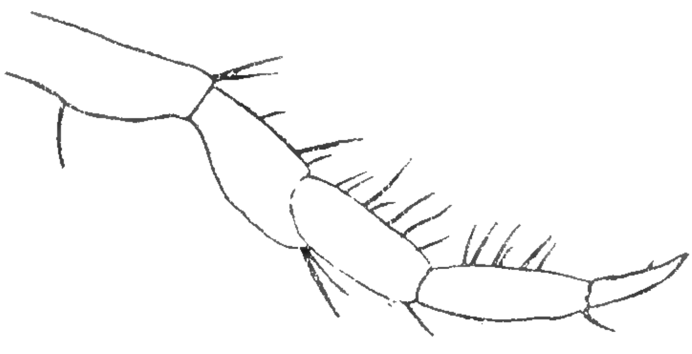

Fig. 4.—Fourth peraeopod of male.

the fourth of the adult male showing no modification for copulatory purposes (fig. 4). The fifth, sixth, and seventh peraeopoda are long and slender, very spinose. The fifth peraeopod is considerably longer than the fourth, the sixth and seventh are longer than the fifth ; the basal joint (coxa) of legs, 5, 6 and 7 is partly covered by the pleuron, the basis is flat and produced posteriorly into an oval lobe, which is broadest on the seventh limb, and in every case bears an inferior notch. The coxal joints of the second, third and fourth peraeopoda are distinct, whilst the basis of each of these limbs is flattened though not as considerably as in the three posterior legs.

The *Pleopoda* are normal, they differ from the other Australian species in having more abundant plumose setae. As a rule, in this species, all the longer setae along the margin of the exopodite are markedly plumose.

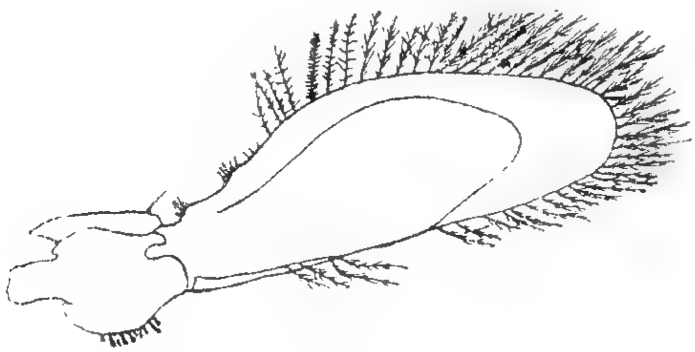

Fig. 5.—First pleopod of male.

The first pleopod of a male (fig. 5), and he second, bearing the penial appendage (fig. 6) which are figured illustrate the great development of the plumose setae.

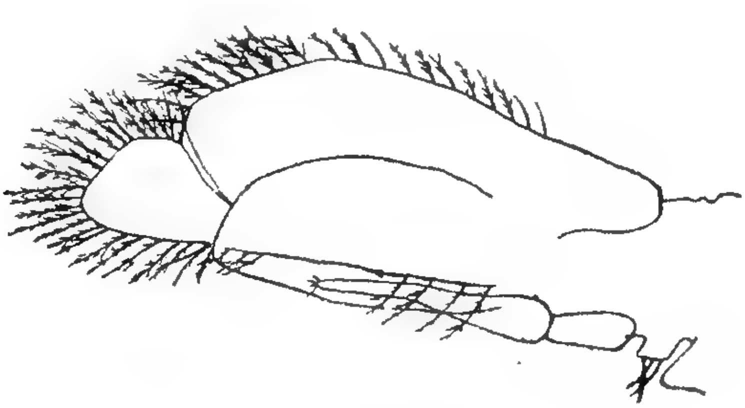

Fig. 6.—Second pleopod of male.

Uropoda are long, the ba al join reaching the end of the telson, the peduncle is stout, grooved longitudinally on its upper surface, each margin bearing 5 or 6 spines which increase in size distally,

the inferior margin is smooth. The inner ramus is as long as the peduncle, bears three spines on its upper margin and one below, it has two large strong terminal spines set in a cluster of smaller spinules and setae, the outer ramus is shorter and less robust, and bears one enlarged terminal spine set among spinules and hairs.

At the base of the peduncle the sixth pleon segment bears several long stout spines, two are placed on a slight swelling or tubercle above the articulation, another is situated between a cluster of setae on the lower margin.

Remarks.—This first Western Australian species of the genus is very unlike the South Australian *P. latipes* and appears to be most closely related to *P. australis* of New South Wales, Victoria, and Tasmania; to *P. shephardi* of New South Wales and Victoria, and to *P. capensis* of Table Mountain, South Africa, from which it is however, easily distinguished by its larger eyes, the size and proportions of the first antenna, the shape of the propodus of the first peraeopod (guathopod), the unmodified fourth peraepod of the full grown male and the degree of expansion of the bases of the fifth, sixth, and seventh peraeopoda. The shape of the telson, as well as the size and armature of the uropoda are also distinctive features of importance.

The presence of the animal in swamps and lakes of the coastal plain at an altitude of less than 60ft. and its (apparent) absence from the water courses and swamps of the hills, are probably due to the distribution of water during the dry summer months.

I am indebted to the Director of the Australian Museum, Sydney, for the opportunity of examining specimens of *P. australis* and *P. shephardi*, and to my friend, Professor F. Wood-Jones, of Adelaide, for specimens of the *P. latipes*, which he discovered at Hergott, in 1920.

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Contributions to the Fauna of Western Australia, No. 5.

By **L. Glauert**, F.G.S.

(*Read* Nov. 13, 1923. *Issued March 1*, 1924).

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CRUSTACEA.

Family LIMNADIIDAE.

Eulimnadia cygnorum Dakin.

Eulimnadia cygnorum Dakin, Proc., Zool. Soc. Lond., 1914, p. 299, pl. I., figs. 9–13.

Five specimens, Nos. **10750/54**, four being adult females with ova, and one an immature individual, were collected at Cannington, the type locality, on the 29th September, 1923. They are of interest as by some of their characters they approach the older species *E. rivolensis* of Brady 1886.* They are larger than Dakin's type specimens with which they have been compared, agreeing with *E. rivolensis* in this respect. They also correspond with this species, as redescribed by Sayce†, in the shape of the shell, the lines of growth, the outline of the lateral plate of the tail, and the shape of the denticles which are less acute than in *E. cygnorum*. On the other hand they closely approximate to Dakin's species in the shape of the head, number of limbs, shape of the terminal claw as well as in the shape and size of the enlarged terminal denticle on the lateral plate.

The ova differ from Sayce's figure of the egg of *E. rivolensis* in being much less spinose. Dakin gives no description. The length of the four adult females is about 9 mm.

Family—LYNCEIDAE.

Lynceus tatei (Brady).

Limnetis tatei .... Brady, Proc. Zool. Soc. Lond., 1886, p. 84, and fig.

Lynceus tatei .... Sayce, Proc. Roy. Soc. Vic., XV., 1902, p. 258, figs. E1, E2, E3.

,, ,, ... Dakin, Proc., Zool. Soc. Lond., 1914, p. 303.

* Brady. Proc. Zool. Soc. London—1886—p. 84.
† Sayce. Proc. Roy. Soc. Vic.—XV.—1902—p. 245—pl. XXXII.

Specimens, No. **10749**, were collected at Cannington associated with the preceding species. They agree closely with Sayce's description and figures.

The species has been recorded from Rivoli Bay, South Australia (Brady); near Sydney, N.S.W. (Sars.); Ros-town and Elwood, Vic. (Sayce); and Busselton, W.A. (Dakin).

Family SPHAEROMIDAE.

Cilicæa tridens Baker.

Cilicaea riden .... Baker, Trans. Roy. Soc. S. Austr., XXXIV., 1910 p. 81, pl. XXIII., figs. 1 to 12.

One specimen, No. **10408**, an adult male, has been recognised among Sphaeromids, collected from a sponge at Cottesloe, in June, 1923.

A local specimen is in the collection of the Biological Department of the University; this was collected at the Cambridge Street Beach.

GENUS ISOCLADUS.

The genus *Isocladus* was established by Miers in 1876*, to receive *Sphaeroma armata* Milne-Edwards, and *S. spinigera* Dana, which differ from the true *Sphaeroma* in the presence of a long slender median process on the last thoracic segment in the male. It was diagnosed "Convex, somewhat wide posteriorly, seventh segment of the pereion in the male with a long, median, dorsal spine. Terminal segment of the pleon narrowing posteriorly, and acute at the extremity. Appendages of the pleon subequal, of a slightly sigmoid shape, and acute at the extremity."

In 1906, Miss Richardson † amended this description as follows:—"Last thoracic segment in the male with a slender median process, produced backward, abdomen composed of two segments. Terminal abdominal segment similar in both sexes, without notch. Branches of the uropoda in the male are large, broad plates. Maxillipeds with the second, third and fourth articles of the palp produced into lobes. Exopod of third pleopod two-jointed. Pleopods of the fourth and fifth pairs have the endopods thick, fleshy, with transverse folds, the exopods two jointed." "The type is *Isocladus armatus* (Milne Edwards)."

? Isocladus excavatus (Baker).

Zuzara (*Isocladus*) *excavata*, Baker, Trans. Roy. Soc., S. Aust., XXXIV., 1910., p. 84, pl. XXIV., figs. 4 to 6.

* Ann. Mag. Nat. Hist.—(4)—XVII.—1876—p. 228.
† Proc. U.S. Nat. Mus.—XXXI.—1906—p. 13. Published 23/7/1906.

A number of specimens, No. **10755,** collected in a rock pool at Cottesloe, in October, 1923, are, with hesitation, considered to belong to this species. They differ from Baker's figures and descriptions in the following featu es—Each segment of the peraeon bears a row of small granules subterminally. The process of the seventh segment is cylindrical, becoming abruptly narrower at the tip, to form a short blunt point. In 13 of the 17 specimens collected, this segment bears a small tubercle close to the posterior edge, on each side, nearly half-way between the base of the process and the epimeron. Four specimens have the process well developed, but the lateral tubercle either absent or rudimentary. Three specimens, which are considered to be immature, have the lateral tubercle developed, but the process very short. The last segment of the pleon has a well marked subterminal granular area. The flagellum of the first antenna has from ten to twelve joints, and that of the second antenna from thirteen to fifteen joints

The larges specimen is 7·5 mm. in length, and nearly 5 m.m. in width. The colour is whitish, punctuate with black, the pleon is coarsely marbled in black and white: the rami of the uropods are like the peraeon, the "venation" is distinctly marked.

Baker's description was based upon a single specimen: it is therefore possible that a larger seri s from South Australia would include forms identical with those obtained at Cottesloe.

The granulation on the paraeon segments and the pair of tubercles on the last of the series are reminiscent of Stebbing's *Cyclura venosa.**

In many respects the animal is very close to *I. magellanensis* Richardson† from Mayne Harbour, Owen Island, Strait of Magellan, South America. I would suggest the name *granulosa* for this Western Australian Isopod if fur her investigation should prove it to be distinct from the South Australian orm.

Family LEUCOSIIDAE.

Leucosia pubescens Miers.

Leucosia pubescens Miers.—Trans. Linn. Soc. Lond. (2)—Zool. I, 1877, p. 238, pl. 38, figs. 22 to 24.

A fine male specimen, No. **10239,** of this species was found at South Beach, Fremantle, by Mr. L. C. Langoulant. It agrees with the description given by Miers and has the short close pubescence on the chelipeds well developed. The coloration is slightly different, there being four elongated white spots on the cardiac region which are neither mentioned by Miers nor shown in his figure.

* Journ. Linn. Soc. Lond. Zool.—XII.—1874—(1876)—p. 146—pl. VI. Later Stebbing altered the name to *Cycloidura venosa* as the previous name was preoccupied. It was decided subsequently that Cycloidura is merely a synonym of Leach's genus Zuzara.

† Proc. U.S. Nat. Mus. XXXI.—1906—p. 14—fig. 18.

The length of the carapace is 25 mm., and its greatest breadth 22 mm.

The type locality is Shark Bay. This crab does not appear to have been recorded elsewhere, so that its discovery at Fremantle considerably extends its known area of distribution.

Family GALATHEIDAE.

Galathea australiensis Stimpson.

Galathea australiensis Stimpson, Proc. Acad. Nat. Sci. Philad., X., 1858, p. 251 (89).
,, ,, Miers, Rep. Zool. Col. 'Alert,' 1884, p. 277, Plate XXXIA (the figure is marked B on the plate).
,, ,, Stimpson. Smiths. Misc. Coll. XLIX., Art. III., p. 230, 1907.

The type specimen of this species was collected by Stimpson "among sponges dredged from a muddy bottom in six fathoms in Port Jackson, Australia." Haswell in his catalogue of Australian Crustacea (1882) records it from Port Jackson and Port Stephens, whilst Miers, in his account of the 'Alert' Crustacea, adds Port Denison, Port Molle, the Arafura Sea, Cumberland Island, Slade Point, Flinders Island and Shark Bay. The discovery of a single specimen, **10674**, a female with ova upon a living purple sponge, in the course of being cast up by the sea, at Cottesloe, thus extends the range of the species some 450 miles down the West coast of Australia.

The colour of the animal in life was similar to that of the sponge upon which it was found, its bright red eyes forming a strong contrast to the uniform tint of the rest of the body. The colour of Stimpson's type (also a female) was "reddish with some bluish on the carapax, fingers of the hands tipped with dark purplish brown." The fingers do not gape, in this respect resembling Stimpson's type, and differ from the male described and figured by Miers.

The dimensions are :—Length of carapace 6·5 mm., width of carapace 4·5 mm. ; length of rostrum 2 mm., length of chelipeds 9·5 mm.

Family HYMENOSOMATIDAE.

Elamena truncata (Stimpson).

Trigonoplax truncata Stimpson, Proc. Acad. Nat. Sci. Philad. X., 1858, p. 109—(55).
Elamene truncata .... A. Milne-Edwards, Nouv. Arch. Mus., Paris IX., 1873, p. 323.

Elamena truncata .... Alcock. Journ. Asiat. Soc. Bengal, LXIX. 1900, p. 386.
„ „ .... Baker. Trans. Roy. Soc. S. Aust. XXX., 1906, p. 112, pl. II., fig. 2, 2a, d.
Trigonoplax truncata.... Stimpson. Smiths. Misc. Coll. XLIX., Art III., 1907, p. 146.
Elamena truncata .... Kemp. Rec. Ind. Mus., XIII., 1917, p. 272, figs. 22, 23.

This little crab was first collected by Stimpson "at Ousima and among the reefs opposite Napa, Loo Choo." It has since been obtained at "Samoa and Viti Islands," (Mus. Godeffroy), India (Henderson); Nicobar Islands (Alcock); the Andamans (Kemp); Ceylon (Henderson); New Caledonia A. Milne-Edwards); and South Australia (Baker). It is never common, very few specimens being recorded from any one locality. Its presence (a single specimen) at Cottesloe is therefore an interesting link in the chain of distribution.

Family SQUILLIDAE.

Squilla scorpio Latreille.

Squilla scorpio ... Latrielle, Encycl. Méthod., X., 1825, p. 472.
„ „ .. Miers. Ann. Mag., Nat. Hist., 5) V., 1880, p. 18, pl. II., fig. 7.
„ „ .... Kemp. Mem., Ind., Mus., IV., 1913, p. 42, pl. II., fig. 30.

A specimen of this Mantis Shrimp, No. **10549,** caught at Forrest River, near Wyndham, was presented to the Museum by Professor Nicholls.

The species is an addition to the fauna of Western Australia, its previously recorded distribution being from Karachi to the Malay Peninsula, Celebes, Borneo, and Northern Australia (Port Essington).

ARACHNIDA.

Family BUTHIDAE.

Isometroides angusticaudus Keyserling.

Isometroides angusticaudus ... Keyserling, in: Arachn., Austr., II., 1884–1889, p. 19.
„ „ .. Kraepelin, in: Das Tierr: Lief. 8: Scorpiones und Pedipalpi—1899, p. 40.
„ „ .... Kraepelin in Res. Mjoberg's Swedish Sci. Exp., Austr., 1910–1913. Arkiv. för Zoologi. K. Sv. Vetenskapsak: 10, No. 2, 1916, p. 21, fig. 1.

The genus *Isometroides*, according to Kraepelin, 1916, is one of the greatest rareties in collection. It contains two species, *I. vescus*, Keys, and *I. angusticaudus*, Keys. The dry incomplete type of the former is in the Berlin Museum, the type of the latter was originally in the Museum Godeffroy, but cannot now be traced.

The published records would indicate that *I. vescus* is represented in collections by the single type and that the sole representative of the other species is a specimen collected in the Kimberley District, W.A., by Dr. E. Mjoberg, on the 17th September, 1911. On the other hand, it is quite possible that the species are present in the collections of Australian Museums although this has, up to the present, not been made public.

Mr. S. Oliver, of Warriedar Station, near Yalgoo, has recently presented to the Museum a little Scorpion, found at Lake Monger, which agrees very closely with Kraepelin's detailed description of *Isometroides angusticaudus* (1916, p. 21), although the proportions of the vesicle and aculeus are 3 : 3 not 4 : 2.

Also the five rows of dark markings on the tergites are increased to seven, of which the central series is scarcely visible to the naked eye, being reduced to a minute black dot on the posterior portion of the dorsal keel of each segment. The colour of the first three caudal segments is like that of the trunk, not yellow, and that of the 4th and 5th caudal segments and of the vesicle more intense, the fifth segment being very dark brown, almost black.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth

Goongarrite, a new mineral from Comet Vale, Western Australia.

By Edward S. Simpson, D.Sc., B.E.

(*Read* December 11, 1923.—*Issued* March 1, 1924.)

A long series of minerals is known having the general formula $xM''S.yM'''_2S_3$, in which M'' is Pb, Hg, Fe, Ag_2 or Cu_2, and M''' is As, Sb or Bi, whilst the ratio x : y ranges from 1 : 6 to 12 : 1. Sixty-two species of this series have been more or less satisfactorily established: some of them of quite common occurrence, such as the "fahl ores," others confined to small accumulations in single localities. Such a series is unusual in the mineral kingdom, and is reminiscent of some of the series of carbon compounds.

Of the group in which x : y is 4 : 1, only two representatives have previously been described*, viz., jordanite, $4PbS.As_2S_3$, and meneghinite, $4PbS.Sb_2S_2$ A mineral recently discovered at Comet Vale on the shores of Lake Goongarrie, forms a third member of this series, having the formula, $4PbS.Bi_2S_3$. For this new mineral the author proposes the name "Goongarrite."

The mineral forms three or four per cent. of the total mass of a quartz vein occurring in an Archaean amphibolite which Jutson† shows to be traversed by small quartz porphyry dykes, derived from a granite mass situated only half-a-mile away to the north. A little of the mineral has also been found in the amphibolite close to the vein. Attention was first drawn to it owing to the high silver results (up to 140oz. to the ton) obtained when portions of the vein were subjected to fire assay.

Goongarrite forms small irregular masses, plates and strings in translucent quartz, no other metallic minerals except native gold and the products of its own weathering being associated with it. The structure of the mineral in the smallest masses is somewhat fibrous, but the larger masses may be described as platy sub-fibrous, the thin plates which are produced by crushing having a tendency to be much longer than they are wide. This sub-fibrous, often slightly radiating structure, is at times discernible on sections of the masses not parallel to a prominent cleavage. This cleavage, which is apparent in all fragments, shows most of the masses of the mineral to be composed of more than one individual. A second cleavage not at right angles to the first is often to be seen on the larger individuals. It may represent the second face of a prismatic cleavage.

* There is a doubt whether the fahl ores belong to this group or the 3 : 1 group. Possibly they include members of both groups.

† Geological Survey of W.A. Bulletin No. 79.

No crystal structure, beyond the cleavages, was observed except in the case of one small mass in which several other imperfect faces could be seen with a lens. This was partly freed from the enclosing quartz and other goongarrite individuals and set up in a Goldschmidt two circle goniometer.

The following readings were obtained :—

Face.	Polar distance.		Azimuth.		Notes.
m^1 unit prism ...	90°	0′	36°	$4\frac{1}{2}$′	Large, excellent image.
m^4 unit prism ...	90°	0′	— 36°	$4\frac{1}{2}$′	Large face.
b^1 clinopinacoid ...	93°	23′	90°	44′	do.
b^2 clinopinacoid ...	92°	41′	— 90°	40′	do.
x prism	95°	1′	— 18°	36′	Very small.
y prism	89° ±		— 75°	11′	do.
r unit hemi-dome	44°	14′	— 0°	3′	Large.
v unit hemi-dome	51°	17′	179°	22′	Number of disconnected facets.
r pyramid ...	63°	29′	70°	16′	Small brilliant.
s pyramid ...	58°	27′	113°	14′	do.
t pyramid ...	16°	29′	60°	6′ ±	Very small.
pyramid ...	9°	42′	— 123°	33′ ±	do.

The nomenclature of the faces in this table must be looked upon as tentative only, in view of the single imperfect crystal measured and the rather poor and often multiple images obtained from all the faces except that marked m^1. The several faces in the prism zone did not yield a uniform polar distance, hence several settings were tried. The final figures adopted in the table were based upon a setting which assumed the edge m^1m^4 to be parallel to the vertical axis. Three separate settings gave the following angles in the prism zone :—

Setting.	m^1m^4.		m^1b^1.		m^4b^2.	
A	72°	23′	54°	41′	54°	28′
B	72°	27′	54°	18′	54°	0′
C	72°	9′	54°	40′	54°	36′

Dana gives for jordanite and meneghinite respectively—
m^1m^4, 56° 31′, 55° 45′: m^1b^1, 61° 45′, 62° 8′.

The figures obtained do not enable the crystallisation of goongarrite to be determined but they are not at variance with the inference that like its two congeners, this mineral is monoclinic.

The density determined with a pycnometer on the fine powder is 7·29. From this the molecular volume is calculated to be 202. That of jordanite with d = 6·39 is 188: that of meneghinite with d = 6·40 is 202. The mineral is brittle, with a hardness on Mohs' scale of 3·0.

Goongarrite is irregularly distributed through the quartz, and in order to obtain material for analysis, several of the richer portions of the vein filling were crushed to pass a 90 mesh sieve and then treated several times with methylene iodide of density 3·3 to remove quartz and any other light mineral. Finally it was hand-picked under a lens to remove any visibly composite grains. The material so collected was found still to carry 1·72 per cent. of quartz. After deducting this, the results of the analysis were :—

Goongarrite, Comet Vale—

	per cent.	mols.	
Lead, Pb	54·26	2,619	2,707
Zinc, Zn	·06	9	
Iron, Fe	·17	30	
Silver, Ag	1·05	97 ÷ 2	
Gold, Au	*Nil*	...	
Bismuth, Bi	28·81	1,378	1,387
Antimony, Sb	·11	9	
Arsenic, As	*Nil*	...	
Sulphur, S	15·24	4,573	4,783
Selenium, Se	·24	30	
Tellurium, Te	*Nil*		
	99·94		

Only vessels of silica and platinum were used in the analyses and double precipitations of each constituent were made whenever possible. The molecular ratios are 3·96 : 2·03 : 6·99 which are very close to 4 : 2 : 7 required by the formula $4PbS.Bi_2S_3$. The structural formula may be—

$$\begin{array}{ccccccccc} Pb & — & S & — & Bi & — & S & — & Pb \\ | & & & & | & & & & | \\ S & & & & S & & & & S \\ | & & & & | & & & & | \\ Pb & — & S & — & Bi & — & S & — & Pb \end{array}$$

The appreciable percentage of silver in the mineral is much greater than that recorded for any specimens of jordanite or meneghinite, but other members of the series $x\,MS.yM_2S_3$ in certain regions contain large proportions of this metal, *e.g.*, andorite, the fahl ores, etc.

The absence of arsenic from goongarrite, and the almost total absence of antimony is noticeable. In this connection it is to be

observed that no bismuth and only very small amounts of antimony have been found in jordanite, whilst no bismuth and only very small amounts of arsenic have been found in meneghinite. In the presence, however, of large amounts of lead, such as occur in these minerals, it is possible that small amounts of bismuth have been overlooked.

Small proportions of selenium, such as were found in this mineral, are not uncommon in the double sulphides of lead, bismuth, etc.

The most striking product of weathering observed in the upper portions of the deposit, both in the quartz vein and adjacent amphibolite, is bright yellow bismutite, both as direct pseudomorphs and as films in adjacent fractures. Massive grey cerussite is similarly distributed and at times a little anglesite can be detected by chemical tests. It is probable that the relatively high silver contents of some of the well oxidised ore is due to the presence of cerargyrite, but there is no ocular evidence of it.

The chemical properties of goongarrite so far determined are as follow:—

Strong (10E) hydrochloric acid decomposes the mineral in the cold, with rather rapid evolution of hydrogen sulphide, the process being hastened by slight warming. Solution is complete except for traces of silver sulphide and chloride.

Dilute (5E) nitric acid has very little effect even upon heating, but stronger acid attacks the mineral rapidly giving a white residue of lead sulphate.

Out of contact with air the mineral fuses below 950° C. and in a closed tube gives a slight sublimate of Sb_2OS_2. Heated in the air white fumes are given off and large volumes of sulphur dioxide. If the heat be applied gradually to a porcelain crucible containing the mineral, and the temperature be finally raised to a bright red heat globules of a lead-bismuth alloy form, probably by interaction of PbS and Bi_2S_3 with $PbSO_4$ formed during the early stages of the roasting.

The type of this mineral is in the author's collection, whilst co-types have been presented to the Western Australian Museum, Geological Survey of Western Australia, and University of Western Australia.

Summary. A description is given of a new mineral coming from the shores of Lake Goongarrie close to the township of Comet Vale. It is named Goongarrite. Its composition is $4PbS.Bi_2S_3$, forming the third member of the series which includes the two previously known minerals, jordanite ($4PbS.As_2S_3$) and meneghinite ($4PbS.Sb_2S_3$).

By Authority: Fred. Wm. Simpson, Government Printer, Perth.

The occurrence of certain natural cross-breds in Oats and Barley at the State Experiment Farm, Merredin, Western Australia.

By **W. M. Carne**, Botanist, Department of Agriculture, and **E. J. Limbourn**, State Experiment Farm, Merredin.

(*Read* March 11, 1924.—*Issued* March 31, 1924.)

The common cereals—wheat, oats, and barley—are normally self-pollinated. Natural crossing is so rare that it is the rule for plant breeders to grow different varieties in closely adjoining rows without any particular precautions against cross-pollination. Nevertheless, natural cross-breeding does sometimes occur, especially in climates warm and dry at flowering time (2).*

Natural cross-breeding in cereals has been recorded from Experiment Stations elsewhere. Natural crossing in wheat is discussed in an article by Pridham (4), who also gives evidence of its occurrence in Australia. Percival (1) says of 1,400 varieties of wheat grown over some years at Reading, England, that some five or six natural cross-breds occur annually. Howard (2), in India, has recorded 231 natural crosses in wheat. At the University Farm, St. Paul, Minnesota, two or three per cent. of natural crosses occur each year (2). Pridham, in New South Wales, has recorded (3) a natural cross between Skinless and Algerian oats. He is also of opinion (3) that the variety of oats known as "Sunrise" originated in a natural cross which appeared in a crop of Algerian oats. Records of such crosses in barleys are few (2, 8). Hayes and Garber (2) conclude that the available evidence indicates that wheat cross-fertilises more readily than either oats or barley.

ALGERIAN × SKINLESS OATS.

(*Avena sterilis* × *Avena nuda.*)

Algerian oats are characterised by strong, horny, dark-coloured flowering glumes which are closely adherent to the caryopses. The spikelets are normally biflorous, occasionally triflorous. A pubescence occurs at the base of the lower grain of each spikelet. The lower grain is also strongly awned.

Skinless oats have large membranous white or yellow flowering glumes which are not adherent to the caryopses, and the latter are, therefore, described as skinless or naked. The spikelets are multi-

* Numbers in parentheses refer to the bibliography at the end of this paper.

florous, containing three to five flowers. There is an almost complete absence of awns and of pubescence at the base of the grains. At Merredin, Skinless oats flower about ten days later than Algerian.

In 1921 a plant appeared in a row of Algerian oats in the variety test rows at the Merredin Experiment Farm. It was distinguished by the presence of multiflorous spikelets, resembling those of Skinless oats, in the upper portions of the panicles. In the lower portions the spikelets were biflorous and similar to those of Algerian oats. The remainder and majority of the spikelets were intermediate between the two. Seed of this plant sown in 1922 matured only four plants. Of these, one (A) resembled Skinless oats in the character of the spikelets; another (B) resembled Algerian, and two (C) the parent. In 1923 the plants from (A) continued to resemble Skinless; those from (B) Algerian, while from (C) came plants resembling A, B, and C.

Unfortunately, all plants of the last generation were not kept; but there is sufficient evidence to indicate that the original plant was the product of a cross between Algerian and Skinless oats, with the F-1 generation intermediate between both parents, without dominance as regards the number of flowers in the spikelet or hull character. The F-2 generation gives the simple Mendelian ration of 1 : 2 : 1. This agrees with the known results when such a cross is artificially made (2, 5, 6). A similar but reciprocal natural cross was recorded by Pridham (3) at Cowra, New South Wales, in the following words: "A remarkable plant, which from its behaviour, is evidently a natural cross-bred, appeared in 1913 in a plot of Chinese Skinless oats. It was much earlier than the type, and the early stools bore spikes in which the upper spikelets resembled the naked or Skinless oat—three to five flowers to a spikelet; while the lower were like the Algerian oat, with dark-brown hulls and two flowers to a spikelet. Two late stalks had a paler foliage and bore flowers typical of the Skinless oat. Next year the progeny comprised plants which were wholly like Algerian, others exactly like Skinless, and many intermediate in character, showing both hulled and naked grain in the same plants. In 1915 similar variations were found . . . ." From the material saved it is evident that segregation had also gone on in respect to grain colour, pubescence and time of flowering; but it is not possible to work out the ratios. The evidence appears to support the findings of Zinn and Surface (5) that the grain colour works out as a simple Mendelian factor but that pubescence is bifactorial, as many of the heterozygous plants have more pubescence than Algerian oats.

The intermediate spikelets of the heterozygous plants show all gradations between hulled biflorous and skinless multiflorous. The majority have two or three flowers with the glumes membranous, but with more or less adherent thickened midribs. The membranous glumes are more pronounced on the lower than the upper flower of the spikelets. There does not appear to be any constant relation

between the three types of spikelet in each head, though the intermediate types are the most numerous. There is no evidence of dominance as suggested by Von Tschermak and by Zinn and Surface (5), but the large glume influence of the skinless parent is so much more conspicuous than that of the thickened midrib effect of the hulled parent that there is an apparent, but not real, dominance of the skinless type.

It has been shown by various investigators (5, 6) that multiflorous spikelets are linked with skinless grains, and that it is therefore genetically impossible to produce a multiflorous hulled oat.

OTHER NATURAL CROSSES IN OATS.

Plants have been noted this season which are probably natural cross-breds between closely related varieties of oats. It is proposed to test these this year.

SKINLESS × COMMON BARLEY.

(*Hordeum vulgare* var. *trifurcatum* × *H. vulgare* var. *pallidum.*)

Skinless barley is characterised by six rows of spikelets in the head, with each outer flowering glume terminated by a trifurcate hood which appears to be a degenerate group of three spikelets in a reversed position. The caryopses are naked as in common wheat. The straw is yellow, and the grain light coloured.

Common barley has six rows of spikelets, but each flowering glume is terminated by a long awn. The grains are hulled. The straw varies from yellow to purple, and the grain from yellow to almost black.

In 1922 one plant of a hulled, hooded, purple-strawed barley with dark-coloured grain appeared in a row of Skinless barley. In 1923 seed from this plant produced hooded, awned and intermediate types. Differences were also noted in regard to hull character, straw colour and grain colour. As regards awns, the intermediate types have short awns terminated by a hood.

It is unfortunate that all plants were not kept. It is known, however, from artificial crosses (2) that hulled grain is dominant over skinless, and that in the F-1 generation the awns are intermediate, *i.e.* with hoods on short awns. In the F-2 generation, hull character works out as: 3 hulled; 1 skinless and, as to awns, 1 awned; 2 intermediate; 1 hooded. The evidence indicates that a natural cross took place, probably in 1921, between Skinless and a purple-strawed dark-grained common barley. A similar natural cross has been recorded by Harlan (8) in America.

The same results were obtained at Merredin from seed of a grass clump plant found in Skinless barley in 1922, which produced the different types already mentioned and also grass clump plants which did not form ears.

SKINLESS × TWO-ROWED BARLEY.

(*Hordeum vulgare* var. *trifurcatum* × *H. distichon.*)

Two-rowed or malting barley is characterised by the fact that only two (the centre of each group of three) of the six rows of spikelets are properly developed and set seed. The perfect flowers are awned, and the grain is hulled.

In 1920 a two-rowed skinless hooded barley was found in a row of Skinless barley. The progeny of this plant produced similar forms in 1921, 1922, and 1923. This form has no awns on the lateral spikelets, and has hoods on the central ones. Included among them in 1922 and 1923 were plants showing a tendency to become six-rowed, the upper portions of the ears setting seeds in the lateral spikelets. This type of barley is botanically known as *Hordeum intermedium* var. *cornutum* (8). It has been shown by Harlan and Hayes (9) that *H. intermedium* is a homozygous intermediate cross-bred (or rather hybrid) between six-rowed and two-rowed barleys.

It is believed that the plant found at Merredin in 1920 was a homozygous F-2 *intermedium* form, and that its progeny are fertile or potentially fertile *Hordeum intermedium* var. *cornutum.* The evidence indicates that a natural cross occurred between Skinless and a two-rowed barley, probably in 1919.

NATURAL CROSSES IN WHEAT.

On several occasions plants which appear to be natural crosses between varieties of wheat have been noted, but genetic proof has not been sought. It is proposed this year to grow the seed of several suspected cross-breds found during the past season.

SUMMARY.

Evidence is given that natural cross-breeding has, occasionally at least, taken place between markedly different varieties of oats and barley at Merredin. It is more than possible that natural crossing to a greater extent has also taken place between varieties more closely related, and more alike in appearance. The product of such crosses would not be nearly as conspicuous as those here recorded, and would be easily overlooked. Further, as wheat is apparently more ready to cross-fertilise naturally than oats or barley, natural crosses in wheat have probably occurred also, and, as in the common barleys and oats, would not be readily recognised. Plants which were the product apparently of natural crosses between closely related varieties of oats and wheat were noted during 1923. It is proposed to test these during the coming season.

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By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

Australian Formicidae, by J. Clark.

(*Read* March 11, 1924.—*Issued* April 30, 1924.)

This paper is an addition to one previously read before the Society, wherein I added 10 new species to the sub-family *Cerapachyinae*,[1] with notes on the habits of a few of them. In that paper I showed that the females of the genus *Phyracaces* are of three forms—winged, wingless and ergatoid, and figured the two latter forms. In the present paper I describe eight new species, the female of a species previously recorded from Western Australia, and the male and female of a species found in New South Wales and Victoria. An interesting discovery recently made was that of two pseudogynes in a nest of *Ph. castaneus*, n.sp., this nest also contained winged males and females, one deälated female and a large number of workers ; the pseudogynes differ from the workers only by the development of the thoracic sclerites. One specimen has the anterior ocellus present, the other specimen has no traces of ocelli ; in size they equal the large workers. Although apparently a group of rare ants, scarcely represented in the collections of our various museums, I am confident that they are numerous, in both species and numbers, and widely spread throughout Australia, but owing to their small size, retiring habits, and method of hunting, they are rarely seen unless specially looked for. Most of the smaller species may be found early in the morning from day-break to eight or nine o'clock, and in the evening from about five o'clock until dark, when they are out raiding the nests of other ants. The larger species are frequently found raiding nests during the hottest part of the day. The nests are generally indicated merely by a small entrance on the surface of the ground, with no mound or other sign that a nest exists ; occasionally they are found under stones and logs ; as a rule, the nest extends about one foot below the ground level.

Unless otherwise stated, the types of the new species are in the author's collection.

(1.) Jour. Roy. Soc. Western Australia, Vol. IX., pt. II., pp. 72-89, 1923.

Sub-family—CERAPACHYINAE.

Phyracaces angustatus, n. sp. (Pl. VI., 7.)

Female : Length 4·4mm. Ergatoid.

Reddish-yellow ; antennae and legs yellow ; marginations, eyes and ocelli black. Hairs yellow, moderately long, semi-erect, longer and more numerous on the gaster than elsewhere, short and sparse on the head. A greyish pubescence on the antennae and legs.

Head much longer than broad, as broad in front as behind, occipital border widely concave, marginate, the angles sharp ; frontal carinae erect, truncate and confluent behind, extending back to the middle of the eyes ; carinae of the cheeks with a prominent angle in front, extending back to the anterior third of the eyes. Clypeus short and rounded. Eyes moderately large and convex, placed at the anterior third of the head, ocelli large and convex. Mandibles large, triangular, their external border feebly concave, the apical borders finely dentate, coarsely and sparsely punctate. Antennae robust, scapes reaching slightly beyond the posterior margin of the eyes, gradually thickened to their tips ; funicular joints one to nine slightly broader than long, tenth longer than broad, apical joint barely twice as long as the preceding joint. Thorax $2\frac{1}{4}$ times longer than broad, as broad through the pronotum as through the epinotum, sides slightly concave, mesonotal sutures feebly indicated ; in profile the mesonotum and epinotum nearly flat, the pronotum convex and rounded, the epinotal declivity not abrupt ; anterior border of the pronotum feebly marginate, the angles rounded, posterior border of the epinotum nearly straight, marginate, the angles sharp, lateral borders of the mesonotum, epinotum and sides of the declivity strongly marginate. Petiole broader than long, broadest at the posterior fourth, the anterior border concave, the posterior border nearly straight, the sides straight to the posterior fourth, then strongly rounded inward, the posterior corners produced backward as small teeth, all four sides of the dorsum strongly marginate ; in profile feebly convex above, the anterior face rounded, the ventral surface in front produced, but without a tooth-like projection. Postpetiole as long as broad, broader behind than in front, anterior and lateral borders nearly straight, angles rounded, posterior border convex ; the ventral surface with a small sharp projection in front. A deep constriction between the post-petiole and first abdominal segment, the latter being broader than long, with convex sides. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs moderately long and slender.

Hab. : Western Australia, National Park. (J. Clark.)

One specimen found under a stone. This distinct species is not near any other known to me. The sutures though feeble are well defined and mark a stage between the ergatoid females which show no traces of sutures, and those females with all the segments but have no wings.

Phyracaces bicolor, n. sp. (Pl. VI., 9, 10.)

Worker : Length 4·6—5·2 mm.

Black ; head, petiole, tarsi and apical segments of the gaster reddish. Hairs greyish, short, erect, very sparse on the head and thorax, more numerous on the petiole and gaster, abundant on the apical segment. A greyish pubescence on the antennae and legs.

Smooth and shining ; the whole insect covered with sparse shallow punctures, finer and more numerous on the antennae and legs.

Head longer than broad, as broad in front as behind, occipital border nearly straight ; frontal carinae erect, rounded, truncate behind ; carinae of the cheeks with a prominent angle, extending back to the anterior fourth of the eyes, a small branch extending inward to the antennal fovea ; clypeus short and broadly rounded. Eyes large and convex, placed behind the middle of the sides. Mandibles large, triangular, strongly bent at their base, the external border concave, apical border feebly dentate, coarsely and sparsely punctate. Antennae robust, scapes reaching the anterior margin of the eyes, gradually thickened to their apex ; funicular joints one and two as long as broad, three to ten broader than long, apical joint nearly as long as the three preceding joints together. Thorax $1\frac{3}{4}$ times longer than broad, slightly broader through the pronotum than through the epinotum, constricted in the mesonotal region, mesonotal sutures feebly indicated, anterior border of the pronotum slightly convex, border of the epinotum nearly straight ; in profile convex and rounded above, the epinotal declivity abrupt ; all four sides of the dorsum and sides of the epinotal declivity strongly marginate. Petiole about $1\frac{1}{2}$ times broader than long, slightly broader behind than in front, anterior border concave, feebly marginate, angles sharp, posterior border straight, lateral border nearly straight and strongly marginate, produced behind as small teeth ; the ventral surface in front not produced into a tooth-like process. Postpetiole broader than long, broader behind

than in front, anterior border nearly straight, marginate, the margination extending along the anterior third of the sides, which are slightly convex. A strong constriction between the postpetiole and first segment of the gaster, which is broader than long, and broader behind than in front. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs moderately long ; hind coxae with a large translucent lamella at the tip on the inner side.

Female : Length 6-7mm. Ergatoid.

Differs from the worker in its much larger size, and in possessing ocelli ; the scapes are longer, reaching beyond the posterior margin of the eyes. The mesonotal sutures are more clearly defined, and the mesonotum more constricted on the sides. The sides of the petiole and postpetiole are more convex. In the larger female the colour is brownish on the thorax and abdomen.

Hab. : Western Australia, Armadale (J. Clark.)

Described from two colonies ; the members of the first colony were raiding a nest of a small *Iridomyrmex*, the second colony were apparently on a raiding expedition, but were only searching when found. Both nests were constructed in the ground, with open entrances, not under stones. This species approaches *P. gilesi*, Clark, in colour, but more closely in sculpture to *P. neumani*, Clark

Phyracaces brevis, n. sp. (Pl. VI., 5.)

Worker : Length 2·4–2·8mm.

Brown, varying from reddish brown to dark brown on some specimens, petiole and two apical segments of the gaster red ; mandibles, face in front of the eyes, antennae and legs testaceous, marginations black. Hairs yellow, sparse, more numerous on the gaster than elsewhere. A fine yellowish pubescence on the antennae.

Smooth and shining, mandibles coarsely and sparsely punctate ; frontal area finely reticulate. Head very sparsely punctate, thorax and postpetiole with large shallow scattered piligerous punctures, finer on the petiole and gaster.

Head longer than broad, as broad in front as behind, occipital border concave, sides evenly convex ; frontal carinae short, carinae of the cheeks prominent, forming a blunt angle, extending back to the anterior margin of the eyes. Clypeus short, nearly straight. Eyes large and convex, placed well in front of the middle of the sides. Mandibles large, sub-triangular, deflected, external borders concave, apical borders indistinctly dentate. Antennae robust, scapes bent near their base, gradually thickened to their apex,

extending to near the posterior margin of the eyes ; first joint of the funiculus twice as long as broad, as long as the second and third together, two to five as broad as long, six to eight broader than long, ninth and tenth longer than broad, apical joint as long as the three preceding joints together. Thorax one and one-third times longer than broad, slightly broader through the pronotum than through the epinotum, sides feebly concave, anterior and lateral borders of the pronotum convex, angles rounded, lateral borders of the epinotum convex, posterior border nearly straight and feebly marginate, borders of the pronotum, mesonotum and epinotum submarginate: in profile the pronotum slightly convex and rounded, mesonotum and epinotum nearly flat above, epinotal declivity sloping, sides strongly rounded. Petiole broader than long, broader behind than in front, anterior border concave, submarginate, angles sharp, posterior border concave, emarginate, lateral borders evenly convex, marginate, angles not projecting ; in profile convex above, the anterior face vertical, the ventral surface in front with a broad projection, nearly half the length of the surface, with a small sharp tooth in front directed backward. Postpetiole broader than long, anterior and lateral borders strongly convex. A deep constriction between the postpetiole and first abdominal segment, which is broader than long with convex sides. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs short, the hind coxae with a short, broad, rounded translucent lamella at the tip on the inner side.

Hab. : Western Australia, Hovea. (J. Clark.)

The nest of this species contained a large number of larvae and pupae, but the female was not found.

Phyracaces castaneus, n. sp. (Pl. VII. 7–14.)

Worker : Length 6-6·5mm.

Bright castaneous ; femora and tarsi darker, tibia and marginations brown. Hairs yellow, long and pointed, more numerous on the gaster than elsewhere, sparse on the head and thorax, a few short adpressed hairs on the petiole and postpetiole. A greyish pubescence on the apical joints of the antennae.

Smooth and shining, head and body very finely reticulate, petiole and postpetiole with some small shallow punctures, abdomen with scattered piligerous punctures, head and thorax very sparsely punctate.

Head longer than broad, as broad in front as behind, broadest at the eyes, which are placed behind the middle of the sides, and are large and convex, occipital border widely but not deeply concave ; frontal carinae large, extending back to about the middle

of the eyes ; carinae of the cheeks forming a sharp prominent angle, extending back to near the middle of the eyes, a small branch directed inward to the antennal fovea. Clypeus short and rounded, Mandibles large, triangular, the external borders feebly concave. apical border edentate, coarsely and sparsely punctate. Antennae robust, scapes reaching the posterior margin of the eyes, gradually thickened to their apex ; funicular joints one to seven as broad as long, eighth and ninth broader than long, tenth longer than broad, apical joint longer than the two preceding joints together. Thorax about one and one-half times longer than broad, broader through the pronotum than through the epinotum, constricted in the mesotonal region, sutures feebly indicated, the anterior border of the pronotum convex, posterior border of the epinotum straight, sides of the pronotum and epinotum convex, sides of the mesonotum concave, anterior and lateral borders of the pronotum, posterior and lateral borders of the epinotum and sides of the declivity, strongly marginate. Petiole nearly twice as broad as long, broader behind than in front, the anterior border concave submarginate, sides convex, strongly marginate, the posterior angles produced backward and outward as broad flat, translucent teeth ; in profile convex and rounded above, the anterior face convex and protruding in front, the ventral surface in front with a short blunt tooth directed slightly forward. Postpetiole broader than the petiole, broader in front than behind, anterior and lateral borders convex and marginate, the margin ceasing abruptly at the posterior fourth of the sides. A deep constriction between the postpetiole and the first segment of the gaster, which is broader than the postpetiole and broader than long. Pygidium truncate, submarginate, minutely spinulose on the sides and tip. Legs long and slender.

Pseudogyne : Length 6–4mm. (Fig. 10.)

Differs from the normal worker in having the thoracic sclerites well developed, almost as in the female, but with no traces of wing sclerites. On one specimen the anterior ocellus only is present, it is large and convex, there are no traces of the posterior ocelli ; the other specimen has no traces of ocelli. In all other details they are identical with the workers.

Female : Length 7mm.

Resembles the worker, but larger and more robust ; eyes larger and more convex, and with large prominent ocelli. Thorax fully developed and winged ; wings hyaline, with yellowish veins, pterostigma dark brown ; on the fore wings all the veins before the costal, median and submedian cells becoming obsolete and indistinct, apical portion of the discoidal cell also becoming obsolete ; the veins of the hindwings obsolete and indistinct. Colour and pilosity as in the worker.

Male : Length 6·5mm.

Blackish brown ; abdomen castaneous, mandibles and antennae testaceous, legs brown, tarsi reddish. Hairs yellow, long, pointed, suberect. A fine greyish pubescence on the antennae.

Smooth and shining, head coarsely punctate, frontal area finely and densely punctate, pronotum finely and densely punctate, anterior portion of the mesonotum coarsely and sparsely punctate, the disc with scattered shallow piligerous punctures, epinotum and petiole finely and densely punctate, gaster with scattered piligerous punctures.

Head, including the eyes, broader than long, strongly convex and rounded behind ; frontal carinae erect, subparallel, reaching the anterior ocellus ; frontal area represented by a deep pit, extending beyond the middle of the eyes. Clypeus short and rounded. Mandibles large, triangular, sharply bent at their base, external borders concave, apical borders indistinctly dentate. Antennae with thirteen joints, robust, scapes extending to the middle of the eyes, all the funicular joints longer than broad, cylindrical. Thorax one and two-third times longer than broad, broader through the pronotum than through the epinotum ; pronotum convex in front of the sides, rounded on top, mesonotum strongly rounded and convex, without a mayrian furrow, but with parapsidal furrows distinct, epinotum with convex sides and straight, marginate, posterior border, epinotal declivity abrupt, marginate on the sides. Wings hyaline, veins yellowish, pterostigma dark brown ; forewings long, reaching the tip of the abdomen, the costal, median and submedian cells complete, but all the veins between these and the apex are obsolete and indistinct ; hindwings with only the basal portion of the costal vein showing. Petiole as broad as long, broader in front than behind, anterior border feebly concave, angles sharp and slightly projecting outwards in front, lateral and posterior borders convex. Postpetiole broader than long, broader behind than in front, broadest just behind the middle, anterior border straight, sides convex. First segment of the gaster about as long as broad. Pygidium rounded at the tip. Cerci absent. Genital appendages blunt, retracted. Legs long and slender.

Hab. : Western Australia, Hovea. (J. Clark.)

Described from a colony containing workers, females, males, and two pseudosynes, also many larvae and pupae. This species is close to *P. clarki*, Crawley, and should perhaps have been described as a subspecies of that form, but the sexes of the latter being unknown, I prefer to regard *castaneus* as a species. It is distinguished by its smaller size and more slender build, larger petiole and postpetiole, longer and more slender legs. This species also resembles *P. punctatissima*, Clark, and like it, has the habit of hunting singly on the ground with the abdomen turned up over the back while running ; the nests, too, are similar.

Phyracaces inconspicuus, n. sp. (Pl. VI., 1, 2.)

Worker : Length 2·6–3mm.

Red, antennae and legs brownish, marginations black. Hairs yellowish, short, numerous and adpressed on the petiole, long and erect on the apical segments of the gaster. A thin greyish pubescence on the antennae.

Smooth and shining ; mandibles coarsely and sparsely punctate, head and thorax finely reticulate, and with sparse shallow punctures ; petiole finely and densely punctured, postpetiole with scattered shallow piligerous punctures, the gaster sparsely punctate.

Head longer than broad, broader behind than in front, occipital border truncate, concave and marginate, the margination extending along the sides to near the eyes ; frontal carinae erect, encircling the antennal insertions in front, extending back to near the middle of the eyes ; carinae of the cheeks forming a prominent angle in front, extending back to near the posterior margin of the eyes, a small branch directed inward to the antennal fovea. Clypeus short and rounded. Mandibles large, triangular, their external borders concave, apical borders finely dentate. Antennae robust, scapes gradually thickened to their apex, extending slightly beyond the posterior margin of the eyes ; funicular joints one to four as broad as long, five to ten broader than long, apical joint longer than the two preceding joints together. Thorax about $1\frac{2}{3}$ longer than broad, slightly broader through the epinotum than through the pronotum, slightly constricted in the mesonotal region ; anterior and lateral borders of the pronotum, and sides of the epinotum convex, posterior border of the epinotum concave, mesonotal sutures feebly indicated ; in profile convex and rounded above, the epinotal declivity steep ; all four sides of the dorsum and sides of the epinotal declivity strongly marginate. Petiole broader than long, broader in front than behind, the anterior border concave and submarginate, posterior border nearly straight and emarginate, lateral borders convex and strongly marginate, the posterior angles produced backward and outward as small sharp teeth ; in profile slightly convex and rounded above, the anterior face vertical. Postpetiole broader than long, broader behind than in front, anterior border slightly convex, lateral borders convex and marginate. A strong constriction between the postpetiole and first segment of the gaster, the latter much broader than long, sides convex. Pygidium truncate, submarginate, minutely spinulose on the sides and tip. Legs moderately long and stout, the hind coxae with a large triangular translucent lamella on the inner side at the tip.

Female : Length 3·4mm. (Deälated.)

Resembles the worker, but larger and more robust ; eyes larger and more convex, ocelli large and convex. Thoracic sclerites fully developed, stumps of wings distinct, colour and pilosity similar.

Hab. : Western Australia, National Park. (J. Clark.)

Phyracaces larvatus, Wheeler. (Pl. VII., 1–6.)

Wheeler, Proc. Amer. Acad. Arts and Sc., 53, 3, 1918, pp. 257–8, Fig. 15. *Worker.*

Female : (Hitherto undescribed). Length 6–6·7mm.

Resembles the worker, but much larger and more robust ; eyes larger and more convex, ocelli large and convex. Thoracic sclerites fully developed, winged ; wings hyaline, not reaching the tip of the gaster, veins yellow, pterostigma dark brown, all the veins before the discoidal cell obsolete and indistinct ; hindwings with the costal, subcostal, externomedian and anal veins well developed at their base, becoming obsolete at their apex, discoidal cell feebly indicated.

Male (hitherto undescribed). Length 5·9–6·4mm.

Black, terminal joints of the antennae and the tarsi brownish. Hairs grey, long and pointed, longer and more numerous on the apical segments of the gaster. A fine greyish pubescence on the antennae and legs.

Mandibles coarsely punctate ; frontal area finely and densely punctate, head rugose and finely punctate ; pronotum, disc of mesonotum, scutellum and epinotum coarsely rugose ; sides of the mesonotum very finely reticulate and with scattered shallow piligerous punctures.

Head, including the eyes, broader than long, broadly convex and rounded behind, occipital border strongly marginate, the margination extending along the cheeks to the middle of the eyes ; frontal carinae subparallel, extending back to the posterior third of the eyes, bending outward on top of the antennal fovea behind, frontal area with a deep excavation forming an antennal fovea. Clypeus short, feebly rounded. Mandibles large, triangular, sharply bent at their base, external borders concave, apical borders finely and sharply dentate. Antennae robust, thirteen jointed, scapes cylindrical, almost reaching the posterior margin of the eyes ; all the funicular joints longer than broad, cylindrical, apical joint pointed. Thorax $1\frac{1}{3}$ times longer than broad, anterior border of the pronotum convex and marginate, sides convex, rounded

above ; mesonotum large, convex and rounded above, mayrian and parapsidal furrows large, Scutellum convex and rounded above, twice as broad as long ; posterior border of the epinotum straight and marginate, epinotal declivity abrupt, sides feebly marginate. Petiole slightly broader than long, anterior border straight and marginate, the marginations extending along the anterior half of the sides, which are convex, posterior border convex, angles rounded ; the ventral surface in front with a broad flat projection directed forward, and a small sharp tooth behind directed backward. Postpetiole broader than long, broader behind than in front, anterior border convex and rounded, feebly margined at the angles which are produced as tooth-like projections, lateral borders convex and feebly marginate in front ; the ventral surface with a long sharp tooth-like projection in front. First segment of the gaster much broader behind than in front. Pygidium convex and rounded. Cerci absent. Genital appendages retracted. Legs moderately long.

Hab. : Victoria, Ferntree Gully (F. P. Spry). Belgrave (F. E. Wilson).

Types in the National Museum, Melbourne.

I have to thank the authorities of the National Museum for permission to examine a large series of all phases of this species, which is the first of the genus to be found in Victoria. The type worker was found at Katoomba, New South Wales.

Phyracaces newmani, Clark.

Worker : Jour. Roy. Soc., W. Aust., Vol. IX., pt. II., p. 82, Fig. 7, 1923.

Female : Length 5·8mm. (Deälated).

Resembles the worker, but more robust, and with large convex ocelli. All the thoracic sclerites fully developed, wing stumps are present. Colour slightly darker. Hairs longer and more numerous, particularly on the gaster.

Hab. : Western Australia. Mundaring (J. Clark).

One female, with several workers, in a small colony under a stone.

Phyracaces nigriventris, n. sp. (Pl. VI., 3, 4).

Worker : Length 2·7–3·2mm.

Head, thorax, petiole and postpetiole red, face in front of the eyes yellowish, gaster and marginations black, carinae of the cheeks, tarsi, tibia, knees and coxae testaceous, femora brownish. Hairs

yellow, short and sparse on the thorax, petiole and postpetiole, a little longer on the abdomen. A thin greyish pubescence on the antennae and legs.

Smooth and shining, mandibles coarsely and sparsely punctate, and finely reticulate, frontal area very finely reticulate, head very sparsely and finely punctate; thorax, petiole, postpetiole and abdomen with scattered shallow piligerous punctures.

Head a little longer than broad, very slightly broader behind than in front, occipital border nearly straight; frontal carinae erect, truncate and confluent behind, extending back to the posterior third of the eyes; carinae of the cheeks forming a sharp angle in front, extending back to near the posterior margin of the eyes, a small branch extending inward to the antennal fovea. Clypeus short and rounded. Mandibles large, triangular, deflected, their external borders concave, apical borders dentate. Antennae robust; scapes, gradually thickened to the apex, extending a little beyond the posterior margin of the eyes, first funicular joint longer than broad, two to nine as long as broad, tenth longer than broad, apical joint as long as the two preceding joints together. Thorax nearly twice as long as broad, as broad through the pronotum as through the epinotum, anterior border convex, emarginate, lateral borders of the pronotum and epinotum convex and strongly marginate, lateral borders of the mesonotum concave and marginate, posterior border of the epinotum nearly straight, marginate; in profile convex and rounded above, the epinotal declivity abrupt, sides marginate. Petiole broader than long, as broad in front as behind, anterior border feebly concave and strongly marginate, posterior border emarginate, lateral borders evenly convex and strongly marginate, produced as blunt flat teeth behind, directed inward and upward; in profile cubic the anterior face vertical, the posterior face rounded from the top to the base; the ventral surface with a broad blunt tooth in front, directed backward. Postpetiole broader than long, convex and rounded in front and on the sides. A strong constriction between the postpetiole and the first segment of the gaster, which is broader than long, sides convex. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs short and stout, hind coxae with a small rounded translucent lamella on the inner side of the tip.

Female: Length 3·5mm. (Ergatoid.)

Resembles the worker, but with larger eyes and large convex ocelli. The mesonotal sutures are more clearly defined. The abdomen is brownish black instead of black as in the worker. The hairs are longer and more numerous.

Hab.: Western Australia. National Park (J. Clark).

This species comes nearest to *P. elegans* Wheeler.

Phyracaces picipes, n. sp. (Pl. VI., 8.)

Worker : Length 4·7mm.

Castaneous, mandibles, antennae and legs brownish, marginations black. Hairs yellowish, long and pointed, abundant on the apical segments of the gaster and on the under side. A thin greyish pubescence on the apical joints of the antennae.

Smooth and shining, head, thorax, petiole and postpetiole very finely reticulate, and with sparse shallow piligerous punctures.

Head longer than broad, broader behind than in front, convex above and on the sides, the occipital border concave, with rather acute inferoposterior corners ; frontal carinae erect, extending back to the anterior margin of the eyes ; carinae of the cheeks with a prominent angle in front, extending back to the anterior third of the eyes. Clypeus short, broadly rounded. Eyes large and convex, placed in front of the middle of the sides. Mandibles large, triangular, strongly bent at their base, external borders concave, apical borders feebly dentate. Antennae robust ; scapes gradually thickened to their apex, extending slightly beyond the posterior margin of the eyes ; all the funicular joints longer than broad, the apical joint longer than the two preceding joints together. Thorax nearly twice as long as broad, broader through the epinotum than through the pronotum, constricted in the mesonotal region, mesonotal sutures feebly indicated, anterior border of the pronotum convex, the angles sharp, posterior border of the epinotum concave, angles sharp ; in profile convex and rounded above, the epinotal declivity abrupt ; all four sides of the dorsum, and sides of the declivity sharply marginate. Petiole slightly broader than the epinotum, $1\frac{1}{3}$ times broader than long, broader in front than behind, the anterior border convex, posterior border nearly straight, lateral borders straight to a little beyond the middle where they suddenly bend inward, forming a feebly concave border behind, the posterior angles forming a feeble tooth-like projection ; in profile cubic, feebly convex and rounded above, the anterior face vertical, forming a right angle with the dorsum, the ventral surface in front with a small hook-shaped tooth directed backward. Postpetiole broader than long, broader behind than in front, anterior border convex and marginate, the margination extending to the anterior third of the sides, which are slightly convex. A strong constriction between the postpetiole and the first segment of the gaster, which is broader than long, and broader behind than in front. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs moderately long and thin, the posterior coxae with a large rounded translucent lamella on the inner side of the tip.

Hab. : Western Australia. Tammin. (J. Clark.)

Described from several workers found running amongst dead grass at the side of the road, no nest of the species was found. The tooth-like projection on the ventral surface of the node is more developed on some specimens than on others. This species is readily separated from all the known forms by the shape of the petiole.

Phyracaces senescens. Wheeler.

Proc. Amer. Acad. Arts and Sc. 53, 3, p. 259, Fig. 16, 1918.
Worker.

New South Wales : Salisbury Court (Type locality) (Wheeler.)

Victoria : Broadmeadows. (C. Oke.)

The specimens found at Broadmeadows by Mr. Oke, agree perfectly with cotypes which I received from Prof. Wheeler.

Phyracaces varians, n. sp. (Pl. VI., 6.)

Worker : Length 4·5–4·8mm.

Castaneous ; sides of the mesonotum and epinotum, the whole of the petiole and postpetiole and marginations brownish black, antennae, anterior portion of the face in front of the eyes, and the legs testaceous. Hairs yellow, long and erect, more numerous on the gaster than elsewhere. A fine greyish pubescence on the apical joints of the antennae and on the legs.

Smooth and shining ; mandibles coarsely and sparsely punctate ; head, thorax and petiole with sparse, scattered, piligerous punctures, more numerous on the postpetiole and gaster. All the body very finely reticulate.

Head longer than broad, as broad in front as behind, occipital border nearly straight, marginate, the margination branching at the inferoposterior corner, one branch extending upward and forward, reaching the posterior margin of the eyes, the other going forward and downward, extending beyond the middle of the eyes ; frontal carinae erect, truncate behind ; carinae of the cheeks prominent, forming a blunt tooth in front, extending back to the middle of the eyes, a small branch extending inward to the antennal fovea. Eyes large and convex, placed near the middle of the sides. Clypeus short and rounded. Mandibles large, triangular, strongly

bent near their base, their external borders nearly straight, apical borders dentate. Antennae robust, scapes gradually thickened to the apex, reaching the posterior margin of the eyes ; funicular joints one to nine broader than long, tenth longer than broad, apical joint as long as the two preceding joints together. Thorax one and three-fourths times longer than broad, as broad through the pronotum as through the epinotum, concave in the mesonotal region, mesonotal sutures feebly indicated, anterior border of the pronotum nearly straight the sides convex, angles sharp, posterior border of the epinotum nearly straight, sides convex ; in profile convex and rounded above, epinotal declivity steep ; all four sides of the dorsum and sides of the declivity strongly marginate. Petiole broader than long, broader in front than behind, anterior border slightly concave and marginate, posterior border submarginate, lateral borders convex and strongly marginate, the posterior angles projecting backward and upward as strong blunt teeth ; in profile cubic, nearly flat above, the anterior face slightly convex, posterior face vertical ; the ventral surface in front with a broad flat tooth-like projection, with a fine sharp tooth on the front edge. Post-petiole broader than long, broader behind than in front, the anterior border nearly straight, the lateral borders straight to the posterior fourth, then rounded to the posterior border ; anterior and lateral borders strongly marginate ; the ventral surface in front with a sharp projection. A deep constriction between the postpetiole and first segment of the gaster which is large and convex. Pygidium truncate, submarginate and minutely spinulose on the sides and tip. Legs moderately long and stout, hind coxae with a large triangular lamella at the tip on the inner side.

Hab. : Western Australia. Lion Mill. (J. Clark.)

The colour of this species varies considerably ; in one specimen it is almost castaneous throughout, and in others the petiole and postpetiole are just a shade darker than the thorax ; the front of the face and the legs are, however, always testaceous.

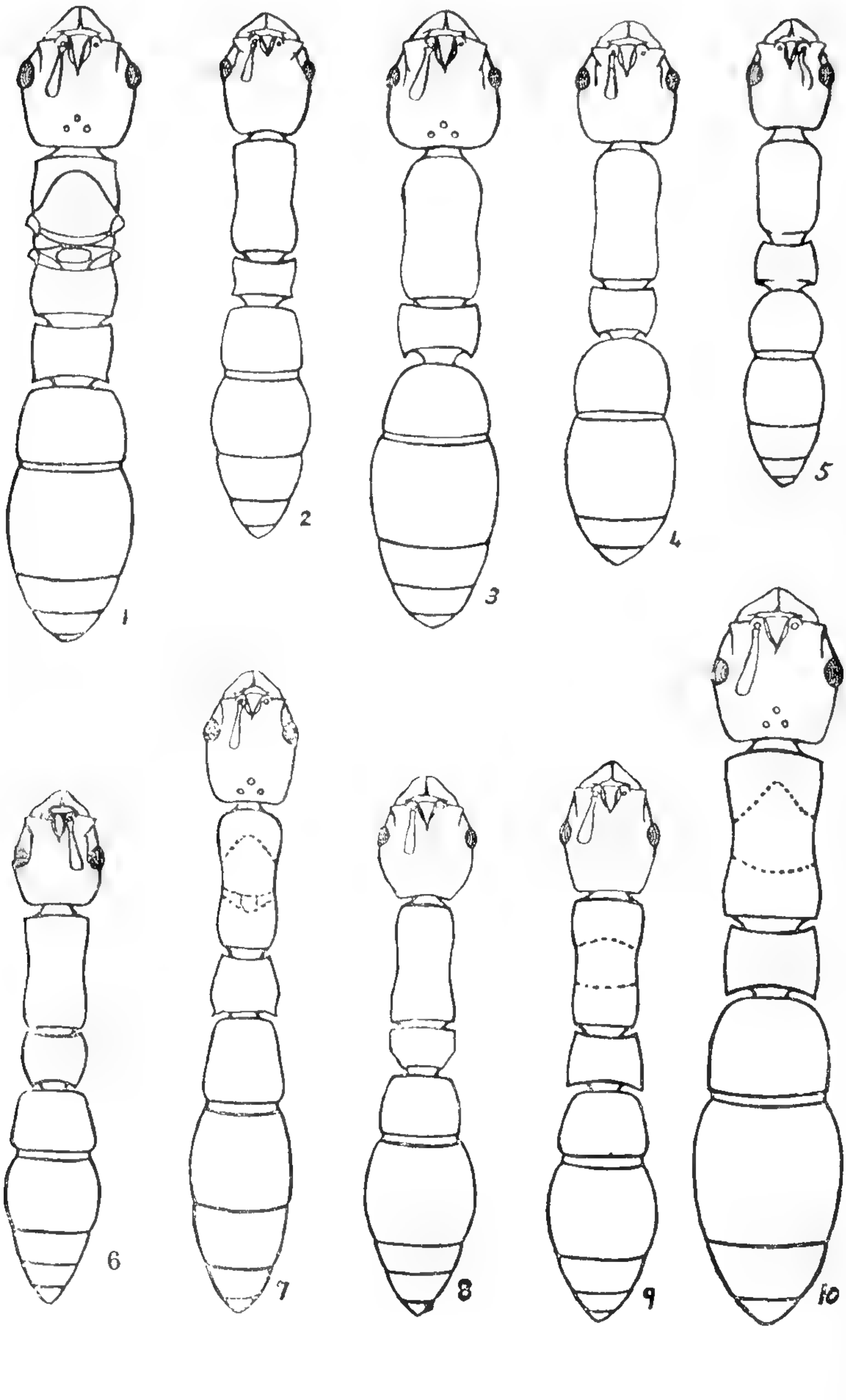
EXPLANATION OF PLATES.

VI.

1.—	*Phyracaces*	*inconspicuus,*	n.sp.,	female.
2.—	,,	,,	,,	worker.
3.—	,,	*nigriventris,*	n.sp.,	female.
4.—	,,	,,	,,	worker.
5.—	,,	*brevis,*	n.sp.,	worker.
6.—	,,	*varians,*	n.sp.,	worker.
7.—	,,	*angustatus,*	n.sp.,	female.
8.—	,,	*picipes,*	n.sp.,	worker.
9.—	,,	*bicolor,*	n.sp.,	worker.
10.—	,,	,,	n.sp.,	female.

VII.

1.—	*Phyracaces*	*larvatus,*	Wheeler,	female.
2.—	,,	,,	,,	male.
3.—	,,	,,	,,	fore-wing of female.
4.—	,,	,,	,,	hind wing of female.
5.—	,,	,,	,,	fore wing of male.
6.—	,,	,,	,,	hind wing of male.
7.—	,,	*castaneus,*	n. sp.,	worker.
8.—	,,	,,	,,	male.
9.—	,,	,,	,,	thorax of female.
10.—	,,	,,	,,	thorax of pseudogyne
11.—	,,	,,	,,	fore wing of female.
12.—	,,	,,	,,	hind wing of female.
13.—	,,	,,	,,	fore wing of male.
14.—	,,	,,	,,	hind wing of male.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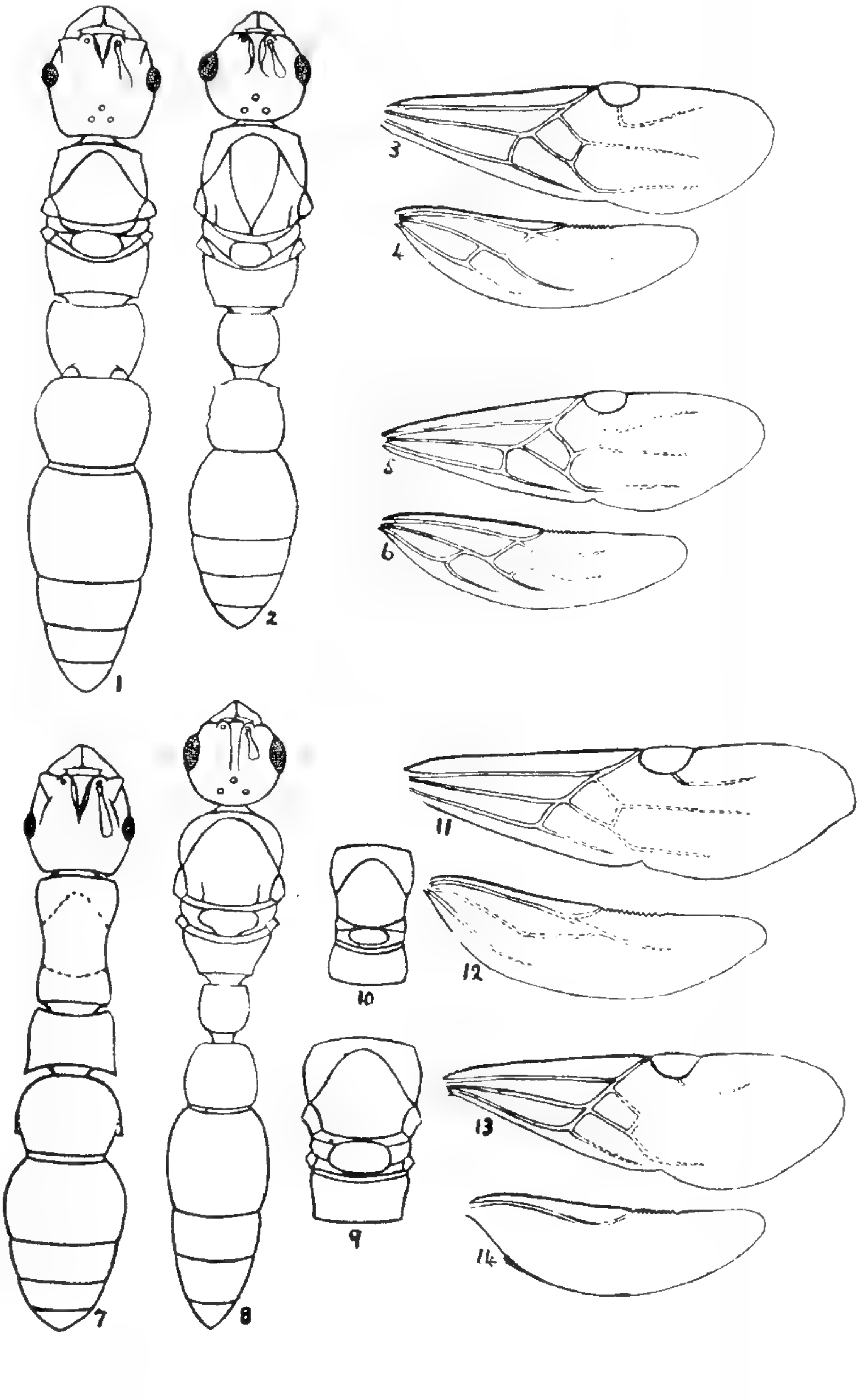

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Phreatoicus lintoni, a new species of freshwater Isopod from South-Western Australia. By **Professor G. E. Nicholls, D.Sc., F.L.S.**

(*Read* March 11, 1924.—*Issued* May 30, 1924).

Rather more than forty years ago the first species of this interesting genus was described by Dr. Chilton, his specimens having been taken from water brought to the surface by a well in New Zealand. In the thirty years succeeding that first discovery, some six, or perhaps seven, other species were added. During that period there were discovered other forms, obviously akin to *Phreatoicus* but differing sufficiently from that genus to warrant the establishment of new genera for their reception, the whole collection being constituted a sub-order, the Phreatoicidea. All of these were restricted in their distribution to Eastern Australasia (being known only from New Zealand, Tasmania, and Eastern Australia) and all of the species of *Phreatoicus*, with but two exceptions †, were sub-alpine forms or from subterranean waters, while the members of the related genera were from similar waters or burrowers in damp earth. The majority were eyeless or with but minute eyes. These facts concerning their distribution as well as their structural peculiarities suggested that the extant forms were the survivors of an ancient surface-water fauna that had persisted to the present time in these scattered hiding places. The antiquity of the group was attested a little later by the discovery, in shales of Triassic age from New South Wales, of a fossil form ('17) differing hardly at all from the typical *Phreatoicus australis*.

In 1914, with the discovery of a new species, recorded under the name *P. capensis*, came confirmation of the belief that this genus had once had a much wider range. This new form was found in the waters on the summit and slopes of Table Mountain in South Africa and its discovery was followed, in 1920, by the finding of abundant specimens of a new species, *in surface waters of low-lying country* in south-central Australia, assigned tentatively to the genus *Phreatoicus* and named *P. latipes* (Chilton/'22). This was a robust form and possessed large, well developed eyes.

† One of these was a blind form *P. kirkii* occurring in a shallow lagoon near the coast of New Zealand, its blind condition being explained upon the supposition that it was derived from an underground form but had reverted to life in surface waters. *P. australis* is said to range from Coast to Mountain top.

During this last twelve months no fewer than three new members of the sub-order have come to light, all from Western Australia. One of these has been referred to a new genus (making the fifth included within the sub-order), the other two western forms are obviously much more closely related to *Phreatoicus*, and one, *P. palustris* Glauert, has already been placed in that genus ('24). It is only after much hesitation that I have included my new species in this genus and, if this and *P. palustris* (and probably *P. latipes* also) are to be retained here, it seems inevitable that the generic diagnosis must be modified somewhat. This is discussed below, when the affinities of *P. lintoni* are considered.

P. palustris has been taken from shallow water in a number of places in the vicinity of Perth, and, like *P. latipes*, only from low-lying country. *P. lintoni* resembles both of these in its robust habit, and the possession of well developed eyes, and was found living under somewhat similar conditions. At present it is known only from a small creek, opening into the King River, a distance of twenty miles or less, north-east from Albany, but almost certainly it will be found to occur over a wide tract of country. It was taken by myself in the course of a collecting trip made, during the present summer, along a part of the southern coast of Western Australia, and I have named it after Mr. G. C. Linton, of the Fisheries Department, under whose guidance I made the visit to the King River.

About half a dozen large females and a number of smaller specimens, mostly immature females, but including five small males, were taken (February 12, 1924), in a small creek near the bridge over the King River. This creek has its source in a spring on the summit of a near-by hill, the orifice at the source having been enlarged to hold a small barrel. Upon the staves of this barrel, which were covered by a luxuriant growth of a filamentous Alga, all the larger individuals were found. On the slopes of the hill the water spread out into a swampy patch which yielded a few specimens but at the base of the hill, on flat ground raised very slightly above the tidal waters of the river, the swamp drains into a shallow channel where the peaty water flows sluggishly. The banks of this channel and the many partly-submerged sticks which almost choke it are clothed with a freely growing moss-like liverwort (one of the Jungermanniales) and it was from beneath this growth as well as in the water, that the greater number of the specimens were secured. No females with brood pouches were seen and the males were all so small as to make it doubtful that they could be mature. Only a few, therefore, were preserved at the time, an attempt being made to get the remainder alive to Perth, there to be kept under observation. Unhappily almost all of them died upon the journey.†

†See however addendum.

Phreatoicus lintoni n. sp.

Text-Figure and Plates VIII. and IX. (figs. 1 and 4–13).

Specific diagnosis.—Body moderately stout, surface smooth with scattered hairs ; eyes large, sub-circular ; head scarcely longer than second peraeon segment. Peraeon sub-cylindrical, the pleura of segments 1–4 slightly developed, not entirely concealing the coxal portion of the legs ; first peraeon segment short, fused with the head, suture distinct ; second, third, and fourth segments equal ; fifth, sixth and seventh successively shorter, the seventh as short as the first. Pleon of moderate length, having (with the telson) a length approximately two-thirds that of the combined length of cephalon and peraeon or slightly less than that of peraeon segments 2–6 ; fifth pleon segment as long (measured dorsally) as the third and fourth together, deeply notched behind. The fusion of pleon segment 6 with the telson indicated by a sutural line running obliquely dorsally from the posterior end of the base of the uropod and marked by a short row of stout spines.

Telson large but not sub-conical, being convex above and concave below, *i.e.*, having a horse-shoe shaped transverse section ; its postero-dorsal border nearly transverse and slightly arched; the dorsal view (Fig. 1*a*) showing a broad and shallow median incisure bounded laterally by paired rounded prominences, each bearing a stout spine ; its inferior margin produced postero-ventrally into notable spines, the most dorsal pair being particularly stout. In terminal (posterior) view the dorsal margin is seen overhanging considerably the anal area, the anus showing as a conspicuous median longitudinal slit, presented postero-ventrally.

First antenna less than half the length of the second, with a many jointed flagellum ; second antenna nearly as long as the head and the first six peraeon segments ; right mandible with secondary cutting edge. Gnathopod strongly sub-chelate (*text figure a*), the "hand" relatively small, the sixth joint sub-triangular, palm deeply concave distally, produced proximally into a densely setose prominence, dactyl scarcely shorter than propod ; fifth, sixth and seventh legs increasing progressively in length, the coxal regions flattened externally and fused to form the inferior extensions of the related pleura, but with distinct sutures, basal joints flat and greatly produced posteriorly to form rounded lobes, notched inferiorly. Pleopoda 3–5 with epipodites, the second pleopod of the male bearing a penial seta $1\frac{1}{5}$ as long as endopodite ; uropoda, long, stout and spiny, the basal joint extending beyond end of telson. (Fig. 1*a*).

Colour.—Generally of a dark brown; on the dorsal surface there is a broad band of darker brown which deepens in shade towards the lateral margins to form a paired, almost black, line, interrupted inter-segmentally. Laterally, the dendritic pigment spots occur more sparingly upon the brown background so that the sides appear of a somewhat lighter shade of brown. In younger specimens a paler, almost olive, tint prevails, with more sparsely scattered black spots.

Length.—The largest specimen, in curved posture, measures about 12mm.; other specimens, slightly less robust, which died extended, reach a length of 14mm., all being females. Greatest breadth of peraeon 3mm. The largest male secured measures barely 7mm. in length.

Habitat.—All the specimens taken were secured from a small sluggishly flowing creek and adjacent swamp, draining into the estuary of the King River, a short distance above the spot where that river discharges into Oyster Harbour.

The following detailed description is based upon two of the larger females and a male of rather less than 7mm.

The *first antenna* (fig. 4*a*) is slender and of considerable length, reaching to about the sixth joint of the flagellum of the second antenna. The well defined peduncle consists of three joints, of which the first and third are of equal length, the second slightly shorter; the first joint is stouter than the second, the third relatively slender. Unmutilated, the tapering flagellum has from fourteen to sixteen joints. The *second antenna* (fig. 4*b*) is much stouter than the first and more than twice as long; of the five joints of the peduncle the proximal three are moderately stout and subequal in length, the fourth nearly as long as the combined length of second and third while the more slender fifth is but slightly shorter than third and fourth together. The flagellum, which has from 27–30 joints, is $1\frac{1}{2}$ the length of the peduncle, almost every joint bearing a terminal circlet of short simple setæ.

Mouth parts.—The *upper and lower lips* (figs. 5, 9) agree, in general shape, quite well with that of the corresponding structures in *P. assimilis* or *P. australis* (as figured by Chilton, '91, figs. 4, 7, and '93, figs. 4, 6), but appear to be rather more densely setose and, in both structures, the more laterally disposed setæ form a detached tuft of longer hairs.

The *mandibles* (fig. 8), also, agree in general form with those of *P. australis* except that the right mandible retains its secondary (inner) cutting edge. In both mandibles the outer cutting edge consists of four stout teeth, the second and third being longer than the first and last. The left mandible has the strongly chitinised

inner row of three teeth, normally found in all members of this sub-order, while the right has retained an inner cutting edge (fig. 8*a*) of three teeth, with serrate edges, the median one being the least prominent and the edge as a whole being paler and much less strongly chitinised than the corresponding structure of the opposite side. In the retention of this right inner cutting edge it departs from the condition described in all of the Phreatoicidea excepting only *P. latipes*, *P. capensis* and *Phreatoicopsis terricola*. An examination, however, of the mouth parts of the Western Australian form (*P. palustris*) recently described by Glauert ('24) proves that this, too, retains such a condition of the right mandible, the inner cutting edge in this species consisting of three pale and slender teeth, in this case the central tooth being the longest. The plate-like process lying between the cutting edge and the molar tubercle is fringed by about fifteen moderately stiff setæ, serrated on either side. The palp has much the usual form and proportions, the stiff setæ at the end of the second joint as, also, those fringing the inner aspect of the third joint are pectinate, the two or three long terminal setæ being simple. Two or three remarkable setæ flexible and branching are to be found upon the palp.

The first maxilla (fig. 6) has its inner lobe rising from a somewhat slender stalk and bearing about seven plumose setæ ; the outer lobe is fringed externally with numerous plumose setæ and armed terminally with about twelve stiff curved spines, serrated to an unequal extent on two sides.

The second maxillæ (fig. 7) appear to be normal, the inner lobe having one margin provided with twenty or more plumose setæ, while the other edge bears a fringe of close set flexible setæ forming a comb-like structure. Both of the short outer lobes are crowned by long, stiffly curved and pectinate setæ.

The *maxillipedes* (fig. 10), likewise, are in general agreement with those of *P. australis* differing in but a few minor details ; the inferior angle of the meros seems to be produced distally to a slightly greater extent. The epipodite, almost circular in shape, has but a single seta on its mesial border while its lateral edge is closely set with numerous fine setæ, a feature recorded in but two or three species of this genus. Corresponding to these there is a feather-like tuft of setæ on the mesial border of the basos.* The plate on the second joint has the normal relations, with three stout coupling hooks. These are rather more widely separated than in *P. palustris* (where all three lie opposite the meros), the proximal in *P. lintoni* being opposite the ischium, while in *P. latipes* of the three hooks the two more proximal hooks are opposite the ischium. The margin of this plate is fringed with long plumose

* A similar tuft occurs on the dorsal surface of the epipodite in *P. latipes* just within the proximal lateral border but appears to be missing from the basos. The margin of the epipodite in that species is free from setæ as Glauert states is the case in *P. palustris*.

setæ but terminally the setæ are simple as indeed are most of the abundant setæ on this appendage. Several setæ suggestive of miniature bottle-brushes are to be found on the basos, and these are commonly seen projecting stiffly ventrally beneath the maxillipedes in position (fig. 1).

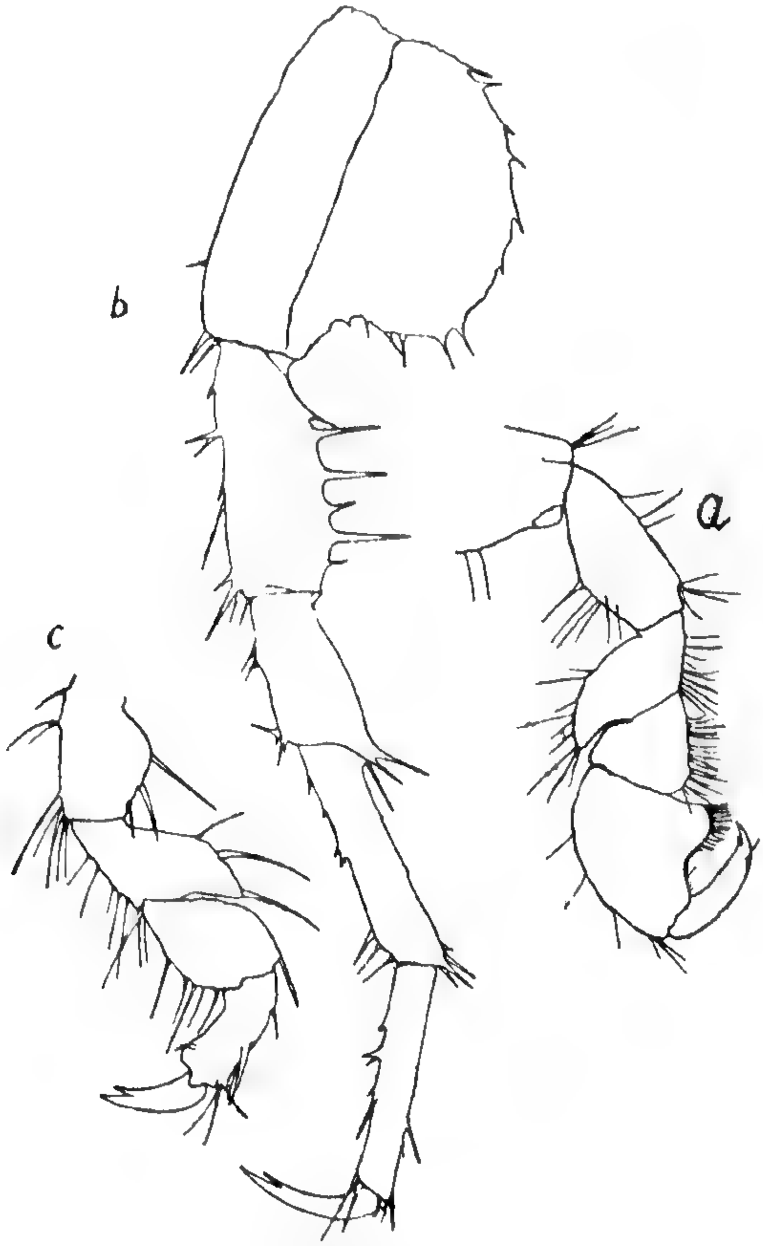

FIGURE : (a.) Gnathopod, (b.) Seventh Peraeopod, (c.) Fourth Peraeopod (male).
(N.B. These are drawn to different magnification.)

Peraeopoda.—The first peraeopod (gnathiopod) like all the succeeding legs has its coxal portion fused with the epimeron. In the female, the shape and proportions of basos, ischios, meros and carpos agree almost exactly with Barnard's descriptions ('14) of those of *P. capensis*. The "hand," however, is distinctive (Text-fig. *a*). Relatively small, the propod is sub-triangular, the base

nearly $1\frac{1}{2}$ the width of the carpos, the anterior margin strongly convex, the palm well defined, concave distally so that the proximal end appears as an outstanding prominence with long stout spiniform setae. The proximal half of the concave portion of the palm bears a narrow ridge, minutely denticulated and running lengthwise. The stout dactylos is slightly longer than the palm; its inner distal end is strongly serrated and the base of the clawed tip has a supporting spinule, the "minute secondary unguis" of Barnard's description. In the largest male, the hand scarcely differs from that above described (unless, perhaps, the palm is slightly less concave) and is not apparently larger than that of a female of the same length.

The second, third and fourth peraeopoda are apparently similar to those of *P. australis.* They are sub-equal in length and slender, with the dactyl much shorter than the propod and have a pronounced secondary unguis. In the male, however, the fourth peraeopoda are slightly modified; the propod is seen to be much wider distally than the related dactyl and has a small palmar surface bearing one short curved spinule (Text-fig. c).

In each of the fifth, sixth and seventh peraeopoda the coxal joint may be discerned externally, its outer surface being flattened and fused with the ventral border of the related pleuron to form a continuous surface. The colouring of these flattened coxal plates is indistinguishable from that of the adjacent pleura, a narrow lighter line alone marking the suture. In all three of these legs there is found an expansion of the basos to form a thin flattened posterior plate, notched inferiorly. The fifth peraeopod is longer than the fourth, the sixth and seventh (Text-fig. b) being much longer than the fifth. All are spinous, certain of the spines, particularly in large specimens, being very conspicuous, very dark in colour and almost rod-like in shape. In all of the peraeopoda there is a well developed secondary unguis.

Pleopoda.—The branchial appendages of the pleon (figs. 11, 12, 13), seem to differ little, except perhaps in size, from those of other species of *Phreatoicus.* In several of my specimens they are seen hanging downwards, sometimes almost vertically (in the position assumed by the pleopods of many Amphipoda), the first pair then reaching nearly to the distal end of the ischia of the seventh thoracic legs. In others they lie, backwardly curved (Fig. 1) and in most they are but partially concealed by the pleura. In one example, the fifth pleopod, carried horizontally, was clearly visible in dorsal view, projecting backwards between the uropoda, extending well behind the posterior border of the telson. This partially exposed condition of the pleopods, doubtless attributable principally to their greater relative size and the considerable development of the fringe of plumose setae, is, I think, quite possibly

a normal state, although unfortunately I did not pay attention to the condition of these appendages in the living animal. Barnard, figuring a somewhat similar condition in *P. capensis*, states that these structures are not thus normally exposed. In *P. palustris*, of which I have examined living specimens, these pleopoda are visible in life, the waving lower edges coming well below the inferior margins of the pleura.

The penial filament, on the second pleopod of the male (Fig. 13), is a stout, slightly curved structure, attached proximally to the basal region which is common to this filament and the endopodite. Otherwise it is free throughout its length.*

Uropoda.—These are long (Figs. 1, 1a), the basal joint being very stout, as long as the inner ramus and extending well beyond the end of the telson. The lower margin is straight and prolonged distally into a spine. On the upper surface a broad groove extends the entire length of this basal joint and its margins are spinose, the outer edge notably so. Of the rami, the inner is considerably longer than the outer one and both are tipped with spines.

Affinities.—Of the genera of the sub-order, other than *Phreatoicus*, each is known from but a single species and of these one only *Phreatoicopsis terricola* is of particular interest in connection with the new species above described. A burrower in damp earth, *P. terricola* is a robust form reaching a length of approximately two inches and, notwithstanding its subterranean habits, has not yet completely lost its eyes although these have become minute. It was distinguished generically from the closely related *Phreatoicus* principally on account of the shape of its tail-piece (sixth pleon segment + telson) and the related appendages, the uropoda.

In this generic diagnosis, Spencer and Hall ('96, p. 13), have described the telson of *Phreatoicopsis* as "large, sharply truncate," whereas that of *Phreatoicus* is stated by Chilton ('91, p. 151) to be "large, sub-conical." Describing *Phreatoicopsis*, Spencer and Hall remark (op. cit. p. 21) "it is difficult by a single word to express the form of the telson, yet it certainly is not 'sub-conical.' Its sudden truncation and horse-shoe shape in transverse section are features which mark it off strongly from the form found in *Phreatoicus.*" From this quotation it will appear that these authors have interpreted the word "sub-conical" in its usual sense of "conoidal" or "nearly conical" and have assumed that the telson of a typical *Phreatoicus* has a surface approaching that of a conical body and, therefore, a transverse section circular or sub-circular

* The same is true of *P. palustris* and of *Hyperoedesipus* ('23), and somewhat similar relations are figured in *Phreatoicoides* ('99), the principal difference in the arrangement of these parts being due apparently to the difference in size, relative to one another, which these structures attain. Chilton's descriptions suggest that these same conditions obtain, also, in *P. australis* ('91, p. 163), *P. assimilis* ('93, p. 195), and P. *latipes* ('22, p. 30). Indeed the latter form and *P. palustris* differ from *P. lintoni* scarcely at all apart from differences in relative size of filament and endopodite. It is, therefore, not quite evident what Barnard had in mind when he speaks of this filament being free in *Phreatoicoides* and *Hypsimetopus* and fused in *Phreatoicius.*

in outline. Chilton's figures of *P. typicus* and *P. assimilis* as well as that of *P. australis* (taken in conjunction with his description) would certainly suggest that such is actually the case.

In *P. lintoni*, however, this sub-conical (helmet) shape to the terminal region, though suggested in profile, does not really exist. Seen from behind, the telson presents a horse-shoe shape with the sides quite widely separated, in posterior continuation of the line of the pleura of the pleon segments. Thus, if the large, broad-based spines which fringe the postero-inferior margin of the telson were to become obsolete, a condition of this terminal piece scarcely to be distinguished from that of *Phreatoicopsis* would result. It was the realisation of this fact that made me hesitate to assign this new species to *Phreatoicus* rather than to *Phreatoicopsis*. An examination of the tail-piece in our other western form *P. palustris* led to the discovery that this was closely in agreement with *P. lintoni* in this respect. Moreover, from Chilton's description of *P. latipes* ('22, p. 26), " terminal segment strongly arched above, sides widely separate below," it was evident that there was yet a third species to which the term " sub-conical " could not apply.

All of these three forms (which, for convenience, I may refer to as " western " forms, occurring as they do entirely outside the restricted eastern Australasian area) have yet another important structural feature in common with *Phreatoicopsis*, namely the retention (in a similarly reduced condition) of the secondary cutting edge in the right mandible*—the retention, that is to say, of a more primitive condition of these appendages, which is apparently still the normal state in some (if not all) Amphipoda.

Furthermore, in these same three forms we have a group showing successive stages in the disappearance of the distinct coxal regions of the hinder peraeopoda. In *P. palustris* (Fig. 2), a short posterior cleft remains to suggest the fact that the lower portion of the downwardly projecting pleura have been furnished by the coxal joints (epimera ?) of peraeopoda five, six and seven. The cleft has vanished in *P. lintoni* but a faint sutural line (unduly emphasized in Fig. 1) still persists ; in *P. latipes* all evidence of this coalescence has disappeared.

Again in these same three " western " species we find a series showing the progressive development of that expansion of the plate-like basos which in *P. latipes* is so strongly developed as to give the animal an Amphipod-like appearance. These expansions are moderately developed in *P. palustris*, *P. lintoni* again showing the intermediate state. As compared with *P. australis*, all of these three forms may be said to show this condition to a marked degree.

Yet another feature possessed in common by these three species is the relatively long and tapering first antenna, in which

* This condition is found also in *P. capensis*, but the profile only of the telson is described in this species.

the number of joints (including the three of the peduncle) varies from twelve to nineteen. *Phreatoicopsis* has fifteen, whereas all* other described members of the sub-order have ten or less and, in most, the structure tends to be club-shaped.

One or two other structural details may perhaps be worthy of note. The male appendages are well developed, even in my quite small specimens, and in the larger males of *P. palustris* which I have examined, they are of considerable size. Chilton's figure shows them well-developed in *P. latipes* and very similar in appearance to those of the two Western Australian forms. In some of the eastern species (*e.g.*, *P. assimilis*) these are said to be absent. In *P. australis* they seem to be small. The penial filament while strikingly alike in these three forms, seems to differ somewhat from that figured in other species. The anal opening is a longitudinal slit which is presented postero-ventrally in all of them, whereas in *P. australis*† it seems to be a crescentic slit disposed transversely. Concerning the condition of these organs in *Phreatoicopsis* I have no information.

Phreatoicus palustris, *P. lintoni* and *P. latipes* seemed, thus, to form a well defined group with distinct affinities to *Phreatoicopsis* and it became necessary to consider whether all of these would not be more correctly assigned to the latter genus, distinguished from *Phreatoicus* by the shape of the telson, the possession of eyes and of a relatively long and tapering first antenna, and the retention of a secondary cutting edge on the right (as well as the left) mandible. Such a group would include forms of robust habit, inhabiting surface waters in low-lying areas and with a much more definitely Amphipod-like appearance. In this view *Phreatoicopsis terricola* would appear as a less typical member which is, in consequence of a comparatively recently acquired burrowing habit, undergoing degeneration, the eyes tending to become obsolete, the expanded bases of the hinder peraeopoda undergoing retrogression, and the uropods dwindling. To this group *P. australis* would appear to be most nearly allied, modified, perhaps, a little by its restricted sub-alpine habit, but retaining eyes and a moderate development of the expanded bases of the peraeopoda.

The question of relegating *P. latipes* to *Phreatoicopsis* or of establishing a new genus for its reception was evidently considered by Chilton, for, in discussing its affinities, that author stated ('22, p. 25), "Although the species is being placed for the present under the genus *Phreatoicus*, it differs from the other members of the genus in at least two characters . . . . the greater expansion of the basal joints of the last three pairs of peraeopoda . . . . .

* I have been unable to verify this statement for *P. kirkii*.

† For specimens of *P. australis*, as, also, of one of *P. latipes* my thanks are due to Mr. Glauert.

(and) . . . . the apparent absence of the coxal joints of all the peraeopoda." And later (op. cit., p. 32), "Until it is possible to make a revision of the Phreatoicidea, this species may be left under the genus *Phreatoicus* . . . . It resembles *P. australis* in having the first peraeon segment short and more or less fused with the head, in this character agreeing also with *Phreatoicopsis terricola*, Spencer and Hall.*"

Chilton proceeds to point out yet further resemblances between *P. latipes* and *P. terricola*, but does not call attention to the fact that these two forms are alike in departing from the sub-conical shape of the telson. It was this omission that led me to examine the telson of *P. australis* in order to ascertain whether or no I had correctly interpreted the original generic diagnosis and I then discovered that *P. australis*, like these western forms, had a horse-shoe shaped section of the telson, perfectly visible when examined from behind.

Probably it is very much less strongly concave below than is *Phreatoicopsis* (of which I have had no material) but it undoubtedly consists of a median portion (the prolongation of the main axis of the body) overhung behind by a terminal projection and continued inferiorly on either side by lateral extensions strictly comparable in position to the pleura of the pleon segments. It thus has quite definitely a horse-shoe shaped, rather than a circular, transverse section and no more than any of the other species which I have examined can it be said to have the telson "sub-conical" although examined in side view, the profile might have suggested that such was its shape. It may well be however, that the term is strictly applicable to *P. typicus* for which form it was originally used and, perhaps, for *P. assimilis* also. In another subterranean form *Hyperoedesipus plumosus* ('23) the telson has the shape of a truncated cone and, therefore, a practically circular shape in transverse section and it is not improbable that in the *Phreatoicus* species with underground habitat the body may likewise have become much more nearly cylindrical and the telson have lost the projecting pleural flaps.

Phreatoicus australis clearly has not attained this condition, but, lacking material of these other species, I cannot determine whether, in this respect, it is atypic and, thus, more nearly resembling the western forms and *Phreatoicopsis* than *P. typicus*. If that be not the case and if all of the species of this genus have a telson which (when seen in transverse section) approximates to the shape of a horse-shoe the separation of *P. terricola* from *Phreatoicus* principally on a difference in the shape *of the profile of the telson* seems scarcely justified.

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* As stated above, this fusion also distinguishes *P. lintoni* and has been described by Glauert for *P. palustris*

Spencer and Hall ('96, p. 21), have called attention, however, to a "small prominent projection of very characteristic form" which terminates the telson in *Phreatoicus* and which is absent in *P. terricola*. An examination of the telson of the western species reveals an interesting series. All lack the projection referred to by Spencer and Hall as distinguishing *Phreatoicus* from *Phreatoicopsis*, but *P. palustris* retains a small rounded apex to the telson (Fig. 2a) which is flanked by a pair of spines. In *P. lintoni* well developed spines are present, but that part of the posterior margin of the telson which separates them is, in this species, actually concave posteriorly (Fig. 1a). This concavity is converted in *P. latipes*, into a narrow and relatively deep incisure (Fig. 3a), so that this form has a terminally cleft telson. Judging from Barnard's figure ('14, Pl. 24, "tels.") the condition of this region in *P. capensis* is not very unlike that of *P. palustris*, but the dorso-lateral spines are not separated from the actual apex ; the terminal and characteristic projection, however, seems to be absent.

In the condition of its telson, *Phreatoicopsis* would appear to come nearest to *P. lintoni*, its transverse (dorsal) margin apparently being quite straight as seen from above.

If, however, Chilton intended the term "sub-conical" to describe the shape of the telson, seen in profile, and if the end region of *P. typicus* does not differ essentially from that of *P. australis*, there would be naturally included within the genus a nicely graded series with *P. latipes*, and *P. terricola* at the one extreme, and *P. typicus* at the other, *P. australis* occupying an intermediate position.

Which of these forms is to be considered, however, as retaining more nearly the primitive condition will depend on what view is taken of the relationships of the sub-order.

Stebbing reviewing this question ('93, p. 390), at a time when two species only of the genus had been described, clearly inclined to the view that their structure justified a belief in a definite Amphipodan affinity. He suggested that Chilton, in his admirable discussion ('93) of the characters of the group, had minimised the importance of certain of the structures.

The condition of the more recently discovered species seems rather to lend support to Stebbing's view, for not only are there present, in these forms, all those characters to which he directed attention, but some of them are even more evident, and new resemblances appear. Thus, the expansion of the second joint of the peraeopoda and the definition of the boundary between sixth pleon segment and telson of *P. australis*, cited by Stebbing, are, in these western species, much more obvious features. In addition, the persistence of the secondary cutting edge of right as well as

left mandible and the greater relative length of the first antenna form fresh points of resemblance. In *P. lintoni* there is also the retention of the clasping arrangement of the fourth peraeopod, which has apparently disappeared in other western forms.

In the alternative view this combination of characters, so suggestive of the Amphipoda, has to be explained as due merely to convergent evolution. It is surely probable, however, that the ancestral Phreatoicid sprang from a marine edriopthalamous stock which invaded surface fresh waters little above sea level. From such situations, the ascent of streams to their source and the occupation of the cold sub-alpine waters would be an easy matter and in time might be expected to produce smaller sub-alpine forms which would be likely to persist in isolated regions long after the low-land forms had disappeared over much of their original range. The derivation of subterranean water forms or of burrowing land forms is readily to be anticipated under the climatic conditions prevailing over much of Australasia. In this view, a form such as *P. palustris* or *P. lintoni* might well be considered as more nearly retaining original characteristics, and its Amphipod-like appearance would be interpreted as evidence of affinity rather than as mere convergent resemblance to the Amphipods.

ADDENDUM.

After this paper had been read, I received additional material from Mr. Linton, including some living specimens. Weather conditions were very unfavourable at the time and none survived more than a few days. The material supplied, nevertheless, some further facts of interest. It included several females with brood pouches; a single large female (without pouch) attained to a length of 20 mm. and there was one male of 10 mm.

From the living material I was able to satisfy myself that the pleopoda were distinctly visible below the pleura of the related segments, a condition which, as noted above, obtains also in *P. palustris.*

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Explanation of Plates.

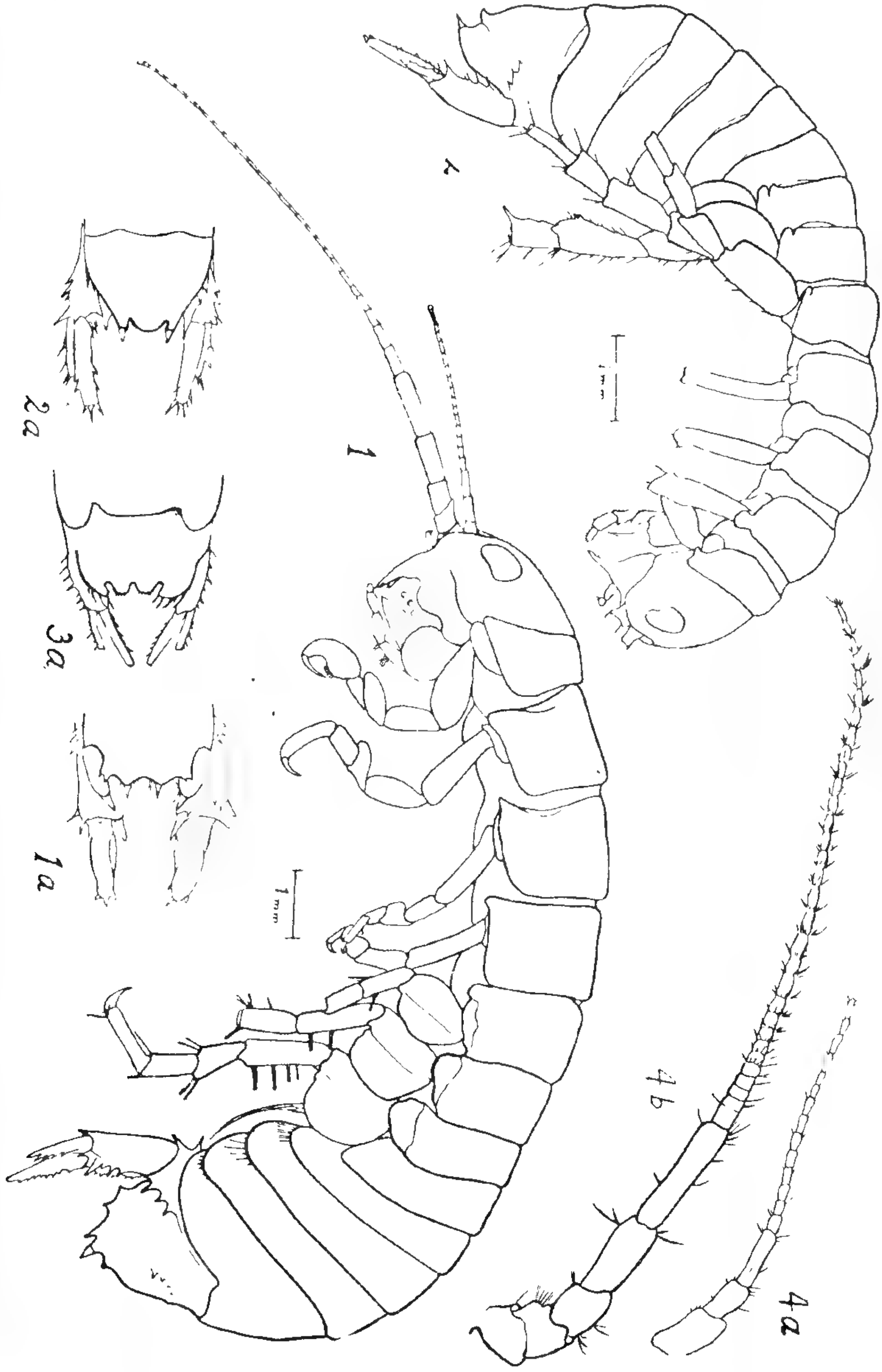
VIII.

1. Lateral view of *Phreatoicus lintoni* (female).
1a. Dorsal view of the telson of a smaller specimen of *P. lintoni.*
2. Lateral view of *P. palustris* (male.)
2a. Dorsal view of the telson of *P. palustris.*
3a. Dorsal view of the telson of *P. latipes.*
4a. First antenna of *P. lintoni.*
4b. Second antenna of the same.

IX.

All figures refer to *P. lintoni.*

5. Upper lip.
6. First maxilla.
7. Second maxilla.
8. Left mandible.
8a. Toothed edges of right mandible.
9. Lower lip.
10. Maxilliped.
11. First pleopod of female.
12. Third pleopod of female.
13. Second pleopod of male.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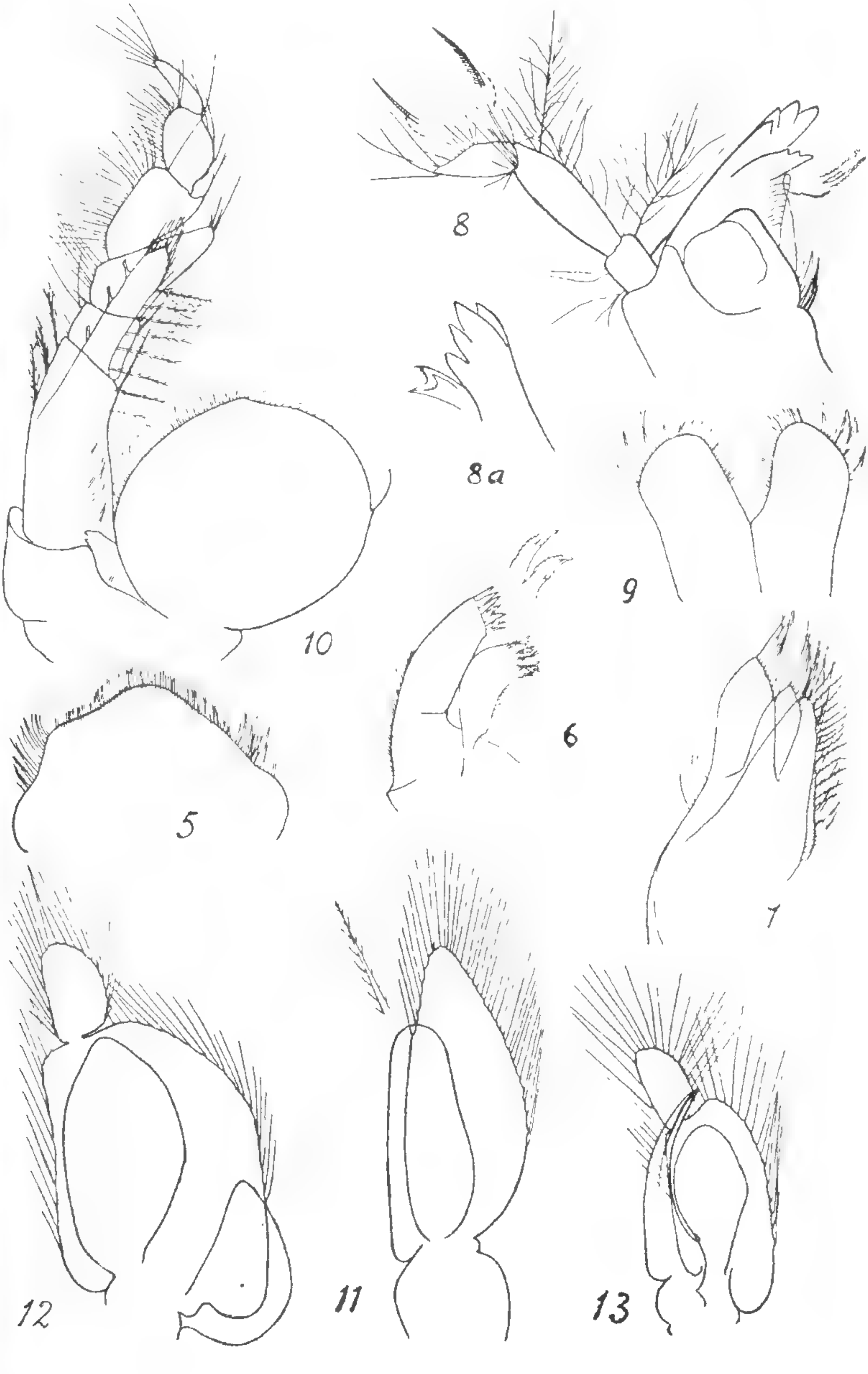

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Neoniphargus branchialis, a new freshwater Amphipod from South-Western Australia.

By Professor **G. E. Nicholls**, D.Sc., F.L.S.

(*Read* May 13, 1924; *Issued July* 7, 1924.)

In a recent paper I described a new species of *Phreatoicus* taken from a small creek discharging into the King River. Associated with it was a small Amphipod, neither form occurring very plentifully. The same water yielded, also, a few small examples of a Crayfish (*Chaeraps preissii*, var. *angustus*), some of these being heavily infested with a Temnocephalan.

The Amphipod proved to be a new species of the genus *Neoniphargus,* the first, so far as I can ascertain, to be recorded from Western Australia. The discovery is of some interest, for, excepting the doubtful European species *N. moniezii,* the genus has been known, hitherto, only from Eastern Australasia, with Tasmania as its headquarters, where it is very generally associated with *Phreatoicus* and *Anaspides.*

Originally constituted by Stebbing (1899) to receive a Tasmanian species, described by Thomson (1883) under the name of *Niphargus montanus*, the genus *Neoniphargus* has been represented by nine species. Of these, seven are peculiar to Tasmania, one (*N. spenceri*) occurs in that island and also in Victoria, while *N. fultoni* is apparently restricted to the mainland. The latter is stated to have been taken from a spring at an altitude of 3,000 feet, *N. spenceri* being found beneath moss at the source of a spring about 2,000 feet, and (in Tasmania) in Lake Petrarch at an altitude of nearly 3,000 feet. The Tasmanian species likewise were all sub-alpine with the single exception of *N. exiguus.* This was taken, with *Phreatoicus australis* (elsewhere a sub-alpine species) in a streamlet, at a spot scarcely above sea level, under conditions closely parallelling those in which the Western Australian species were found.

Neoniphargus branchialis, n. sp.

Specific diagnosis. Head almost as long as the two anterior segments, lateral corners rounded. Side-plates deep, rounded below, with few marginal setæ, 1-3 of equal width, the fourth deeper than broad emarginate, 1½ the width of the third. Pleon segments 1-3 with inferior margins rounded, postero-lateral corners angular; pos-

terior margins of first and second slightly, of the third deeply, notched. Last segment with stout spinule on either side of base of telson, penultimate segment with a cluster of four spinules on either side. Telson twice as long as broad, cleft for four-fifths of its length.

Eyes large, reniform, close to margin of the head. Antenna 1 considerably less than half the length of body, first joint of peduncle longest and stoutest, second and third successively shorter and more slender, flagellum 11-jointed, about equal in length to the peduncle, accessory flagellum small, 2-jointed. Antenna 2 slightly shorter than antenna 1, peduncle long with four joints of which first and second are short and stout, the third elongate, the fourth shorter and more slender; the 8-jointed flagellum of the female scarcely exceeds half the length of the peduncle. In the male the flagellum with but six or seven joints of which three (1-3 or 2-4) bear calceoli. Mandibular palp with third joint slightly shorter than the second; on the first maxilla, the inner plate with but two setæ, outer plate with seven serrate spines, palp of both sides alike, with seven slender spines. Gnathopods 1 and 2 similar and of equal size, sub-chelate, the fifth joint produced into a lobe proximally and not widening distally, sixth joint scarcely quadrate (sub-cordate), palm convex, oblique, minutely denticulate. Gnathopod 2 and peræopods 1-3 bearing branched, lobate accessory branchial vesicles. Uropods 1 and 2 reaching to level of end of telson, uropod 3 elongated, outer ramus with minute secondary joint (?), inner ramus small without apical seta.

Length. Female 8mm., male 6mm.

Colour. In life, a dark grayish green; in spirit, a pale yellowish brown.

Habitat. Taken in February of this year, associated with *Phreatoicus lintoni,* and occurring somewhat sparingly in the waters of a shallow swamp and beneath a leafy liverwort clothing the banks of a small creek draining the swamp and emptying into the King River, W.A.

Detailed description. The body is smooth and free from setæ and spines. The head, measured dorsally, has a length almost exactly equal to that of the first two peræon segments combined. Hinged to its inferior margin there is a small, light coloured plate, approaching semi-circular in shape, which seems to be related to the base of the second antenna. This and the rounded postero-lateral corner of the head are hidden from view by the forwardly projecting side-plate of the first peræon segment. The first four side-plates attain a depth double that of the second segment. They are parallel-sided with rounded inferior margins, the fourth, however, having its pos-

terior border deeply excavate dorsally. The fifth is even wider than the fourth, but is rounded and much less deep than the four more anterior plates. The sixth and seventh are much less conspicuous and the former is deeply notched on its antero inferior border. In the metasome the pleura are considerably produced, with the inferior margin rounded and a well-marked posterior angle. Through the transparent pleura of the pleon region, the conical bases of the pleopods are visible, the side-plates of the peræon being slightly more opaque. The last segment of the urosome bears a pair of stout spinules close to the base of the telson, while on the preceding segment, some little distance to either side of the middle line, the posterior margin is excavate to form a tiny shallow notch lodging a short row of four spinules of which the second and third are the stoutest. The telson, which has a length almost equal to that of the rami of the first uropods, is cleft for nearly four-fifths of its length. It is somewhat narrow and its ends, obliquely truncated, are furnished with three stout spines.

First antenna (Pl. X., A^1). Short and moderately stout, first joint of peduncle nearly $1\frac{1}{4}$ length of second and $1\frac{3}{4}$ length of the third. The flagellum, scarcely as long as the peduncle, consists of 10 or 11 joints, all bearing setæ terminally and, among these setæ, upon all but the first and last articuli, there is a rod-like structure like that figured by Sayce in *N. fultoni* (1902, Pl. 7, A^1). The accessory flagellum is two-jointed, both joints bearing setæ and having a combined length about equal to that of the first two articuli of the primary flagellum.

Second antenna. This differs very little from that of *N. fultoni* as figured by Sayce (op. cit., Pl. 7, A^2), the chief difference being that the penultimate joint of the peduncle is relatively longer in *N. branchialis*, and the 8-jointed flagellum is barely longer than that joint. In the male the flagellum has but six or seven joints of which the three proximal usually bear calceoli.

Mouth parts. The *upper lip* does not differ from that of *N. spenceri* as represented by Sayce (1900, Pl. 40, L^1), but the *lower lip* (op. cit., Pl. 40, 2) has the inner lobes rather more distinctly marked off. In the *mandibles* the spine row has but four, or at most, five, stiffly curved and pectinate setæ. The inner cutting edge in the left mandible consists, however, of four well chitinised teeth scarcely less developed than those of the outer cutting edge, while that of the left plate is delicate and bears several teeth with remarkable serrate edges. The palp has the first joint short, the second is long, the third slightly shorter. In this it differs from the condition in *N. spenceri* (Sayce, 1900, p. 240), but is in agreement with that figured by Thomson for *N. thomsoni* (1893, Pl. 6, Fig. 3), and by G. W. Smith (1909, Pl. 13, Fig. 4) for *N. yuli.* The *first maxilla*

approaches much more nearly to the condition of this appendage in *Niphargus,* the outer plate having seven (instead of *six*) more or less toothed spines. The palp has seven simple spines, the inner plate but two curved, simple setæ, apically situated. The *second maxillae* agree closely with the condition figured by Thomson (op. cit., Pl. 6, Fig. 6) excepting that in *N. branchialis* the outermost seta is strongly developed and spinose and is slightly removed from the rest. The inner margin of the inner plate is not fringed with setæ, again resembling *N. thomsoni* (and *Niphargus*) but differing from *N. spenceri.* In the latter a short spinule represents the well developed outermost spine of the western form.

The *maxillipedes* differ markedly from the corresponding appendages described or figured in all other species of this genus, in the relative shortness of both inner and outer plates. The former does not reach to the distal end of the first joint of the palp, while the latter scarcely extends beyond the base of that joint. Neither of these places is setose to nearly the extent existing in *N. spenceri,* while the apex of the outer plate bears only tooth-like spines; on the inner plate these are represented by five or six more slender spines. The numerous setæ upon the palp are simple.

Gnathopoda. Of practically equal length, the second is perhaps very slightly the stouter, though the hands are of equal size. The most important detail in which they differ from the condition described as existing in other species is that which concerns the shape of the carpos which, in *N. thomsoni,* is described as "broadly triangular," the wide base being distal. A similar condition is figured in *N. spenceri* and *N. fultoni.* In the latter, however, the posterior margin is shown produced into a distally situated knob. Stebbing (1899, 1906) cited this distal widening of the carpos as a feature of generic value, but in the diagnosis of the genus which appears in the work of Smith (1909) this character is omitted, although the latter author nowhere expressly states that his species depart from that condition. His figure of *N. yuli* emphasises the distal knob, but shows also the propod articulating with a part only of the distal border of the carpus.

In *N. branchialis* the gnathopods are generally found folded upon themselves (Pl. X., Gn. 1, Gn 2), in which case the propod seems to rest upon a broad base formed by a wide distal end to the preceding joint. In the extended condition, however, it is seen that the distal border of the carpus upon which the propod actually pivots is relatively narrow and the knob-like process lies at the proximal end; in this species, then, the carpus is widest proximally. The propod has rounded corners and appears sub-cordate or ovoidal with an emarginate proximal border. The curved dactyl is long and stout, closing down upon a minutely toothed, convex palm, its tip lying

between a double pair of spines. Upon the basos of both gnathopoda, particularly the first, are a number of long and flexible setæ. Similar setæ are found also upon the corresponding joint of the first and second peræopoda. Such setæ are represented by Sayce (1900, Pl. 40) as occurring sparingly upon the second gnathopod of *N. spenceri.*

The *Peraeopoda* call for little comment. The fifth perœopod is, as is usual in this genus, distinctly shorter than the fourth, the dactyl in every case terminating in a claw which is not supported by a secondary unguis but is spinose or serrate along its whole length. On the convex outer surface each dactyl bears a single well-developed plumose seta. This is apparently the case, also, in *N. fultoni,* Sayce figuring it upon the second and third peræopod.

The Western Australian species appears to be unusual, however, in the branchial appendages to the segments of the peræon. Normal branchial vesicles occur at the base of the second gnathopods and first to fourth peræopods but, in addition to these, a branched body with obtuse lobes was found attached to the base of the second gnathopods and the first and third peræopods. Upon the detached limb-bearing portion of the latter segment, three of these structures were seen, doubtless the pair normal to the segment and one accidently separated from the preceding segment. There can be little doubt, therefore, that these accessory gills are related to all but the last of the gill-bearing segments. It was the presence of these accessory branchial organs that suggested the specific name.

Upon the second, third and fourth peræon segments marsupial plates are found, lacking, however, the fringe of setæ usually present. What is probably a rudimentary fourth plate is to be seen attached near the base of the third peræopoda. In the one female taken with an egg-laden brood-pouch there seem to be a few fringing setæ on the plates.

Uropoda. The first pair are moderately long, with peduncle longer than the rami; these are of equal length and truncated terminally and armed with a stout spine supported by several smaller spines. The second uropoda are very similar but shorter, not reaching quite to the end of the first pair. The third are longer than the first, and consist of a short stout peduncle and a long rod-like outer ramus furnished with spines at fairly regular intervals and terminating in what might be regarded as a conical spine. It ends, however, in one or more terminal setæ and there can be little doubt that Smith has correctly interpreted it as a rudimentary (vestigial) terminal joint. Along its inner surface the ramus bears a number of long plumose setæ. The inner ramus is a minute scale-like structure, bearing on one margin several long setæ.

Remarks. Neoniphargus branchialis may be readily recognised by the shape of the carpus of the gnathopoda, in which it differs from all hitherto described species. Except for the presence of a knob-like process, this joint has an outline almost rectangular, whereas in the other species of the genus it is described as "broadly triangular," the base of the triangle being the distal border of the joint. Added width is given to this end of the joint in some of these species by a distally situated process. In the western form, a triangular shape to this joint—closely resembling that of the Victorian and Tasmanian species—is suggested when the limb is folded, the proximal margin of the propod then resting against the whole length of the posterior margin of the carpus, the process appearing as the only free portion of the posterior margin. *N. yuli* shows a condition intermediate between that of *N. branchialis* and *N. thomsoni.* In *N. spenceri* this process is apparently undeveloped.

N. branchialis may be further distinguished from previously described species by the possession of branched accessory branchiæ and by the occurrence of *seven* spines on the outer plate of the first maxilla, and by the condition of the maxillipedes. Stebbing (1899) in his diagnosis of the genus, when dealing with the mouth parts of *Neoniphargus*, notes that, in the type species (*N. thomsoni*), these are nearly as in *Niphargus*, except that there are but six, instead of seven, spines on the outer plate of the first maxilla. In the several species which have been described since the appearance of Stebbing's work the first maxilla has been shown to be somewhat variable. but in none have seven spines been found on the other plate of this appendage.

Elongated third uropods are found in all three of the Australian mainland species, whereas they are markedly shorter in the Tasmanian forms. Smith apparently overlooked the condition of these appendages in *N. spenceri* and *N. fultoni,* and inserted in his generic definition ('09, p. 73) the statement "uropoda . . . third pair only just projects beyond the others posteriorly."

In this respect, as well as in the elongated and greatly cleft condition of the telson, *N. branchialis* comes very near to the Australian species of Grammarus, which, according to Smith, are exactly intermediate in structure between the genera Neoniphargus and Gammarus as typically represented by the forms found in the Northern Hemisphere.

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EXPLANATION OF PLATES.

X.

A^1, A^2. First and second antennæ.

Gn. 1. First gnathopod, folded.

Gn. 1a. First gnathopod, extended.

Gn. 2. Second gnathopod,
br. branchia, $br.^1$ accessory branchia.
m. marsupial plate.

L 2. Lower lip.

M^1, M^2. First and second maxillæ.

Md. r., l. Mandibles right and left (toothed edges only).

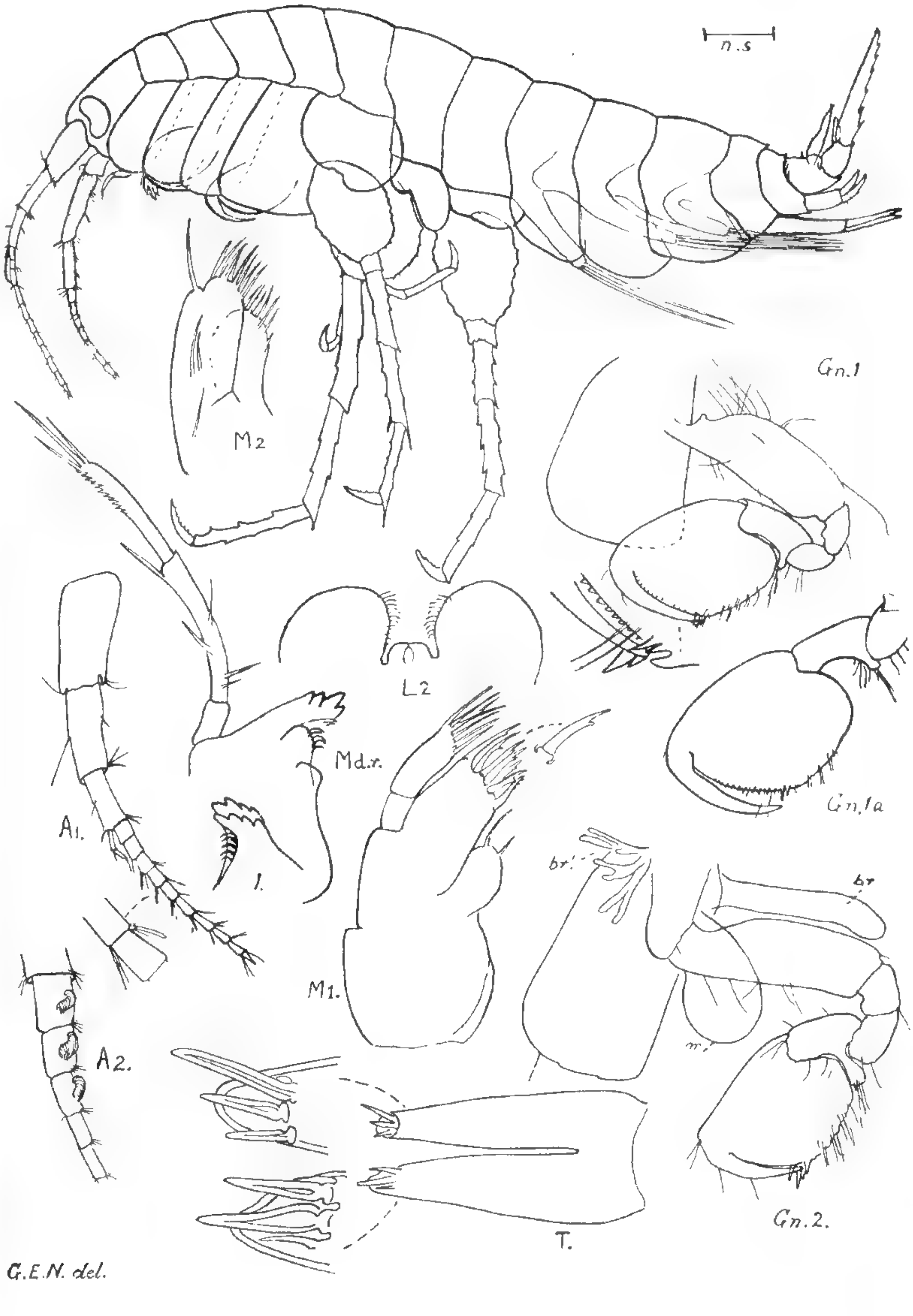
T. Telson.

XI.

Mxp. Maxilliped.

P^1—P^5 First to fifth Peræopoda,
br. branchia, $br.^1$ accessory branchia,
m. marsupial plate, m^1 rudimentary marsupial plate (?).

Ur. 1—Ur. 3. First to third Uropoda. Third uropod drawn on slightly larger scale.



G.E.N. del.

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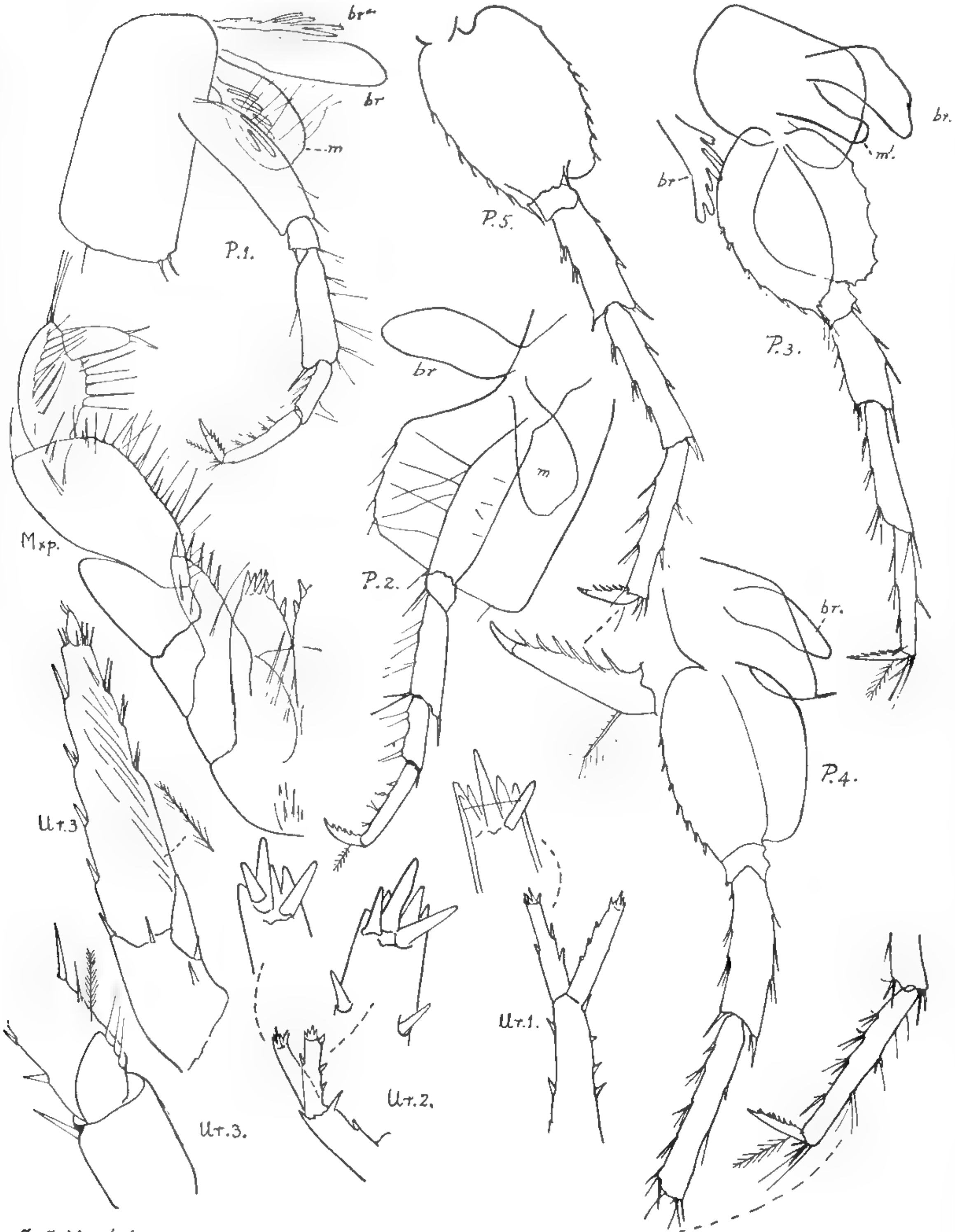

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Note on the so-called Ericopsis formosus Gardner.

By **C. A. Gardner.**

(*Read* July 8, 1924. *Issued* July 30, 1924.)

In December, 1922, I collected, and described from fresh material, the above plant, placing it in the family *Ericaceae* (Jour. Roy. Soc. Western Australia, Vol. IX., Part I., p. 42).

An examination of my specimens at a later date has led to the discovery that the plant is not new, but a species of *Goodeniaceae.* As a comparison of the descriptions of *Leschenaultia* and *Ericopsis* will show, the differences are an oblique corolla and the presence of the indusium in *Leschenaultia,* and a regular coralla and capitate stigma in *Ericopsis.* The other floral parts as regards their arrangment and order are similar.

Leschenaultia tubiflora, R. Brown, "Prodromus," p. 581, is an Astroloma-like plant which may have a perfectly regular corolla-tube equally lobed when fresh, and a closed (not two-lipped) indusium resembling a simple stigma, although there is, as remarked in the description of *Ericopsis,* a raised line in the centre of the summit of the style dividing it into two equal halves, one glabrous, or nearly so, and the other slightly glandular-hairy. When dried, or perhaps at an advanced flowering stage also, the indusium becomes quite evident, and this organ characterises it at once as one of the *Goodeniceae.* The relationship therefore between the ericoid-leaved species of *Leschenaultia* and the *Ericaceae* is very close, especially in external appearances.

At the same time, my specimen cannot be regarded as typical of *L. tubiflora,* although I have not seen the type, and have only had R. Brown's and Bentham's descriptions to guide me, and this mistake might easily be made if, as in this case, specimens are examined in a fresh condition, for the indusium of *L. tubiflora* in my specimens described, and in later ones received from the same locality, appeared as a two-lipped dilation of the style only when the specimens had dried.

Ericopsis was unfortunately described in the absence of fruits.

By Authority: Fred. Wm Simpson, Government Printer, Perth

THEORIES REGARDING THE AETHER, by Professor A. D. Ross, M.A., D.Sc., F.R.S.E.

(Presidential Address- *Read* July 8, 1924; *issued September 15, 1924.*

Despite the importance of electricity from the practical standpoint, it is doubtful whether any other branch of physical science has aroused so much interest as the study of Light. The beauty and variety of optical phenomena, the relative importance of our sense of sight, the fact that light is the main vehicle of interplanetary and interstellar communication—all these make Optics fascinating to the general student as well as to the scientist.

In early times man speculated regarding the nature of light. In the sixth century B.C. Pythagoras suggested an emission theory, but about 350 B.C. Aristotle opposed the idea that light was material, considering it to be a quality or action (Greek, *energeia*) of a medium which he called the pellucid (Greek, *diaphanes*). In his writings we find the suggestion of the theory of an aether, a theory afterwards developed by Grimaldi (1618-1663), Huygens (1629-1695), Thomas Young (1773-1829), and Fresnel (1788-1827). Since the seventeenth century the celestial bodies have no longer been regarded as isolated in space, but as immersed in an aethereal ocean which permitted an incessant conveyance and transmutation of energy. Thus arose the problem, not yet completely solved, as to the relationship which subsists between this luminiferous medium which fills the known universe and the aggregations of matter which occur here and there throughout it.

The problem may be said to have originated in the speculations of René Descartes (1596-1650) in his endeavours to create from the beginning a complete system of human knowledge. While his work was necessarily metaphysical, he also aimed at a mechanical explanation of nature.* He regarded the universe as an immense machine operated by the motion and pressure of matter. "Give me matter and motion and I will construct the universe." He repudiated all idea of action at a distance. Force could not be communicated save by actual pressure or impact, and hence it became necessary to provide explicit mechanism for each known force in nature. He considered that the sun and stars consist of a subtle form of luminous matter and form the centres of immense vortices. They are surrounded by a transparent plenum consisting of an

* See his *Dioptrique* (1638), Météores (1638), and *Principia Philosophiae* (1644).

assemblage of minute spherical particles or globules. The luminous matter and the transparent matter, owing to the centrifugal force of the vortices, are straining away from the rotation centres. The particles press outwards, but, owing to their contact one with another, they cannot so move, and it is this pressure which constitutes light. The transmission of light from luminous matter (say the sun) to opaque matter (say the earth) through the medium of the transparent matter plenum was thus compared to a blind man's perception of the presence of objects by the transmission of pressure from particle to particle along a stick. The diversities of colour and light were ascribed to the different ways in which matter moves and the various colours were connected with different rotatory velocities of the globules.* This association of colour with periodic time was a strange foreshadowing of one of Newton's great discoveries. The law of refraction of light† was established by aid of analogy with the motion of ponderable matter, but the proof required light to move more rapidly in dense than in rare media. Descartes, probably interested by the celebrated treatise *"De Magnete"* published by William Gilbert in 1600, attempted to account for magnetic phenomena by his theory of vortices. A vortex of fluid matter was imagined for each magnet, the vortex matter entering by one pole and leaving by the other. This matter was supposed to act upon iron and steel by a special resistance offered to its motion by the molecules of such metals. The Cartesian system of the universe was doubtless crude in many of its features, but it emphasised the importance of a broad generalisation of knowledge and unification of ideas (such as we now have in the electromagnetic theory of light), and the necessity of considering the relationship between ordinary ponderable matter and the plenum of space.

Robert Hooke (1635-1703), on of the founders of the Royal Society of London, was both an observer and a theorist. He experimented on the colours of thin plates,‡ and the illumination in the geometrical shadow of opaque bodies due to diffraction,§ in both of which matters he had however been anticipated.¶ He was led to theoretical investigations representing a transition from the Cartesian to the fully developed theory of undulations. He took exception to Descartes' view that light is a tendency to motion rather than an "exceedingly quick motion," and from various observations deduced that the motion was of a to-and-fro or vibratory character and of excessively small amplitude. He then stated the necessary properties of the pellucid or transparent medium. It must be homogeneous, susceptible to the vibrations of luminous

* *Principia*, Part iv., par. 195, and *Discours Huitieme*.
† *Dioptrique*, Discours second.
‡ *Micrographia*, p. 47.
§ *Posthumous Works*, p. 186.
¶ Boyle's *Works* (ed. 1772), Vol. i., p. 742; Grimaldi *Physico-Mathesis de lumine, caloribus, et iride* (1665), book i, prop. 1.

bodies, and capable of transmitting this appulse to the maximum distance in the minimum time. Further this propagation must be in straight lines in homogeneous media, the wave-front extending out as an expanding sphere. Hooke was also able to give a mechanical theory of refraction, and his was an advance on Decartes' theory in that the velocity of propagation was less in dense than in rare media. He regarded white light as the simplest type of disturbance, consisting of a pulse at right angles to the direction of propagation, while the prismatic colours arose from the deflection of the wave-front. "The ray is dispersed, split, and opened by its refraction at the superficies of a second medium, and from a line is opened into a diverging Superficies, and so obliquated, whereby the appearance of Colours are produced."*

This theory of colour was however completely overthrown by Sir Isaac Newton (1642-1727), who, by his historic experiment in 1666 on the formation of a prismatic spectrum, discovered that ordinary white light is really a mixture of rays of every variety of colour. At first Newton strove merely to arrive at the general laws of optical phenomena without attempting to formulate hypotheses as to the ultimate nature of the optical processes. He found however that it was impossible to go far without having recourse to hypotheses. He then rejected Hooke's idea that light consists in vibrations of an aether, owing to the apparent incompetence of the wave-theory to account for the rectilinear propagation of light and to explain the phenomena of polarisation. He considered the universe to be filled with an elastic medium or aether which is capable of propagating vibrations in the same way as air propagates sound. The aether penetrates all material bodies and is the cause of their cohesion, while its density varies from one body to another but is greatest in free interplanetary space. It is not necessarily a single uniform substance but may contain various aethereal "spirits" which are respectively adapted to give rise to the phenomena of electricity, magnetism, and gravitation. He suggested† that light might consist of multitudes of unimaginable small and swift corpuscles of various sizes emitted by luminous bodies. Or it might consist in some "corporeal emanation, or any impulse or motion of any other medium or aethereal spirit diffused through the main body of aether." He let everyone form his own ideas, only reserving the supposition that light at least "consists of rays differing from one another in contingent circumstances, as bigness, form, or vigour." Aether was then the intermediary between light and ponderable matter. When a ray of light met an aether stratum of density different from that of the stratum in which it had been travelling, it was, in general, deflected from its previous course. Moreover the condensation

* Hooke, *Posthumous Works*, p. 82.
† Roy. Soc., 9th Dec., 1675.

or rarefaction of the aether due to a material body extended to some little distance from the surface of the body, and so diffraction was "only a new kind of refraction." To those who assumed with Newton that light is not actually constituted by vibrations of an aether—even though such vibrations may exist in close connection with it—the most natural supposition to make was that rays of light are streams of corpuscles emitted by luminous bodies. So, while Newton left a wide choice of hypotheses open, one was invariably selected by the scientific men of the age, and by later writers it has generally been associated with Newton's name. And there is little doubt that this hypothesis was the one which Newton found most convenient in picturing the mechanism in optical phenomena. We find then that Newton supported an emission theory of light, but postulated an all-pervading aether which was modified at least in respect to density by ponderable matter, not only within the material bodies but also in their immediate vicinity. An aether was necessary, as it was differences in density of aether between one material medium and another which accounted for the reflection and refraction of light.

Christiaan Huygens (1629-1695) greatly improved and extended the wave-theory shortly after Roemer's discovery in 1675 of the finite velocity of propagation of light. In his *Traité de la lumière* published in 1690 he improved on Hooke's conception of an outward moving spherical pulse or wave by considering that each surface-element of the wave-front may be regarded as becoming the source of a secondary wavelet, and that the advancing wave-front is the envelope of all such secondary wavelets. He was able to apply this successfully to the explanation of reflection, refraction, and of double refraction in Iceland spar. It was this last mentioned phenomenon which had compelled Newton to abandon the hypothesis that light consisted of waves analogous to waves of sound. On this point Newton was perfectly correct, but while his objection was valid against the wave-theory held by his contemporaries, it was not valid against the theory in the form in which it was stated in the eighteenth century by Young and Fresnel. As Newton said,* "A ray of light obtained by double refraction differs from a ray of ordinary light in the way that a rod of rectangular cross-section differs from a rod of circular cross-section, and it was impossible for a ray to exhibit sides" if it consisted of longitudinal vibrations as in sound propagation.

With the exception of the announcement in 1728 of the discovery of the aberration of light from observations made in 1725-6 of the star *Gamma Draconis* by James Bradley (1692-1762), there was little advance in optical science until the nineteenth century. The aberration of light too was more easily explained on the corpus-

* Newton, *Opticks* (2nd ed.), queries 26 and 28.

cular than on the wave-theory, and it certainly strengthened the supporters of the former hypothesis.

Thomas Young (1773-1829) began to write on optics in 1799. In his first paper* he draws attention to the difficulty in explaining on the corpuscular theory of light why the velocity of emission of a corpuscle should be the same whether the projecting force was that of a feeble spark or the intense heat of the sun itself. A further passage contains a marvellous prophecy of an electric theory of light: "That a medium resembling in many properties that which has been denominated ether does really exist, is undeniably proved by the phenomena of electricity. The rapid transmission of the electric shock shows that the electric medium is possessed of an elasticity as great as is necessary to be supposed for the propagation of light. Whether the electric ether is to be considered the same with the luminous ether, if such a fluid exists, may prehaps at some future time be discovered by experiment." In 1801 he made a great advance in optics in explaining on the wave-theory the phenomenon of Newton's rings by accepting the composite nature of white light and considering the mutual reënforcement and interference of two beams.† In 1803 he applied the theory of interference to the explanation of diffraction phenomena.‡ The year 1817 witnessed a still greater triumph on his part. A consideration of the results of experiments on the interference of polarised light convinced him that the vibrations in light rays were transverse and not longitudinal.§ This showed very considerable insight, for it is to be remembered that the theory of propagation of waves in an elastic solid was yet unknown, and light was always considered by analogy with the vibrations in sound waves.

Augustin Fresnel (1788-1827) had been working for some years on the subject of optics when Young's announcement of the transverse vibrations in light rays was made. He at once realised that this hypothesis fitted in marvellously with the phenomena of crystal optics, and the remainder of his life was devoted to the elucidation of polarisation effects in crystals. In an important memoir‖ he states "The theory which I have adopted, and the simple constructions which I have deduced from it, have this remarkable character, that all the unknown quantities are determined together by the solution of the problem. We find at the same time the velocities of the ordinary ray and of the extraordinary ray, and their planes of polarisation. Physicists who have studied attentively the laws of nature will feel that such simplicity and such close relations between the different elements of the phenomenon are conclusively in favour of the hypothesis on which they are based."

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* *Phil. Trans., Roy. Soc.*, 1800, p. 106.
† *Phil. Trans., Roy. Soc.* (1802), pp. 12, 387.
‡ *Phil. Trans, Roy. Soc.* (1804); Young's *Works*, i., p. 179.
§ Young's *Works*, i., p. 380.
‖ *Mem. de l'Acad.*, vii., p. 45 (1827); Fresnel, *Oeuvres*, ii., p. 479.

By the genius of Young and Fresnel the wave-theory of light was firmly established a century ago, but so far the theory was not strictly a dynamical theory, as the qualities of the aethereal medium had not been defined. They had pointed out that the existence of transverse vibrations might be explained by conferring a new property on the luminiferous aether, viz., giving it power to resist attempts to distort its shape. Clearly there were difficulties in the way. This power to resist change of shape is the property which distinguishes solids from fluids. Could the aether be an elastic solid while the planets and comets moved through it? Sir George Gabriel Stokes (1819-1903) in 1845 drew attention to the fact that such substances as pitch and shoemakers' wax, though so rigid as to be capable of elastic vibration, are yet sufficiently plastic to permit other bodies to pass slowly through them.* The aether might then have this combination of qualities in an extreme degree, behaving as an elastic solid for vibrations so rapid as those constituting light, but yielding like a fluid to the much slower progressive motions of the planets.

This suggestion by Stokes gave an impetus to the development of the theory of elasticity, and we have the important researches of Cauchy, MacCullagh, Neumann, Green, and Boussinesq, some of whom paid considerable attention to the application of their general theory to optical phenomena. In this connection it is noteworthy that Boussinesq clearly indicated† that all space, both within and without ponderable bodies, is occupied by one identical aether, the same everywhere both in inertia and in elasticity, and further that all aethereal processes are to be represented by two kinds of equations, of which one kind expresses the invariable equations of motion of the aether, while the other kind expresses the interaction between aether and matter. Many years afterwards these ideas were revived in connection with the electromagnetic theory, in the modern forms of which they are indeed of fundamental importance. William Thomson, Lord Kelvin (1824-1907) and James Clerk-Maxwell (1831-1879) were also pioneers in this elastic solid theory of the aether, and a noteworthy feature of their work was their mechanical models of the aethereal medium. However, these physicists were led into this field through electrical rather than optical investigations, and we must here glance back at the development of electrical theory.

The experiments of Petrus Peregrinus in the thirteenth century in locating the magnetic poles of a piece of lodestone were instrumental in calling the attention of William Gilbert (1540-1603) to the necessity for detailed study of both magnetic and electric

* *Trans. Camb. Phil. Soc.*, viii., p. 287.
† *Journ. de Math.* (2) xiii., pp. 313, 425 (1868): *Comptes Rendus*, cxvii., pp. 80 139, 193 (1893).

phenomena. He imagined that electric phenomena were due to something of a material nature, which, under the friction used in the process of electrification, is liberated from the glass, amber, sulphur, or sealing-wax, in which under ordinary circumstances it is imprisoned. The friction might conceivably warm or otherwise excite and liberate this humour or effluvium so that it emerged as an atmosphere surrounding the electrified body. Gilbert's theory of electric emanations naturally commended itself to the physicists of the seventeenth century, as it obviated all assumption of action at a distance. The mutual attraction of the electrified body and a light object in its neighbourhood could be explained by imagining the effluvia to have a tendency to condense in other bodies and to have an inherent contractile tendency, or, if preferred, a vortex theory of effluvia might be adopted. The announcement in 1729 by Stephen Gray of his discovery of electric conduction made it impossible to consider that electric effluvia were inseparably connected with the bodies from which they were evoked by friction, and it became necessary to postulate for them an independent existence. Their apparent imponderability was no difficulty to the scientists of the period who were accustomed to include caloric and light in the list of chemical elements.

Soon after this rival theories of electricity developed. Du Fay (1698-1739) showed by a series of experiments that there were apparently two kinds of electricity,* vitreous and resinous, while in 1747 Benjamin Franklin (1706-1790) suggested a one-fluid theory.† The important point, however, was that both theories agreed with the suggestion put forward in 1746‡ by William Watson (1715-1787), that electricity is neither created nor destroyed in the charge or discharge of a Leyden jar but is something which is transferred. These advances rendered adherence to the electric effluvia thory increasingly difficult. Originally it had been supposed that this material was normally present in glass, but could be brought out by frictional electrification, but Franklin's theory of the Leyden jar required glass to be impermeable to electricity. The theory of effluvia was finally overthrown by Aepinus (1724-1802), who found that a condenser could be made with air as the medium separating the two plates. The electric fluid did not then extend beyond the surface of the charged body, and this result, combined with Stephen Gray's observation in 1729 of the similar effects produced by electrified solid and hollow cubes, indicated that the fluid when at rest was confined to the surface of the charged bodies. This established, it appeared that electricity can act at a distance across intervening space.

* *Mem. de l'Acad.*, 1733, p. 464.
† **Franklin**, *New Experiments and Observations on Electricity*, letter ii.
‡ *Phil. Trans. Roy. Soc.*, xliv., p. 718.

The discovery of galvanic or voltaic electricity in the closing years of the eighteenth century opened another method of approaching the subject. For the researches of Oersted (1777-1851), Ampère (1775-1836), Gauss (1777-1855), and Weber (1804-1890) in electrodynamics demanded the existence of an electric medium—not a medium which constituted the electricity itself, but a medium through which the electric and magnetic actions could be exerted. In the hands of Faraday (1791-1867) it was shown* that all the effects of electricity (magnetic, thermal, luminous, chemical, mechanical, and physiological) are obtained equally well whether the electricity has a frictional or voltaic source. In 1838 he advanced a theory of electrostatic induction† in which he compared the particles of the insulating dielectric to a series of small magnetic needles, or a series of small insulated conductors. This conception of action, propagated step by step through a medium by the influence of contiguous particles, was fundamental in Faraday's work. It was carried by him into almost all branches of science, and sufficed to explain electric currents. In 1845 he was successful in finding experimentally a connection between magnetism and light, the powerful field of an electromagnet rotating the plane of polarisation of a beam of light travelling along the lines of magnetic force in a piece of heavy glass.‡ This led him in the following year to publish a short paper on *"Thoughts on Ray Vibrations"*§ which contains the germ of an electromagnetic theory of light. In this paper he suggests that atoms of ponderable matter may be merely fields of force of electric, magnetic or gravitational character surrounding a point-centre, and, as lines of force radiate out through space, light and radiant heat might be transverse vibrations propagated along these lines of force. Hence Faraday suggested the dismissal of the aether, or rather its replacement by lines of force between centres. If the postulation of a luminiferous aether was desirable, Faraday considered that it might also be the vehicle of magnetic force, for it seemed to him not at all unlikely that it should have other uses than merely the conveyance of radiations.

These ideas of Faraday were wonderfully developed by James Clerk-Maxwell (1831-1879) in his electromagnetic theory of light. Thomson‖ had compared electric force to displacement in an elastic solid. Faraday had supposed¶ that when the dielectric is subjected to an electrostatic field, there is a displacement of electric charge on each of the small conductors to which he had likened the particles of a ponderable dielectric; and the motion of these charges

* Faraday, *Experimental Researches*, series iii.
† Faraday, *Experimental Researches*, par. 1679.
‡ Faraday, *Experimental Researches*, par. 152.
§ *Phil. Mag.* (3), xxviii (1846); *Experimental Researches*, iii., p. 447.
‖ *Camb. & Dublin Math. Journ.*, ii. (1847), p. 61; Thomson, *Math. & Phys. Papers*, i., p. 76.
¶ Faraday, *Experimental Researches*, par. 1679.

when the field was varied, was equivalent to an electric current. Maxwell, in adopting Faraday's idea, transformed it; for, whereas the conception of displacement had been applicable only to ponderable dielectrics, with Maxwell* there is displacement wherever there is electric force whether material bodies are present or not. The so-called displacement is, however, in these latter theories a change of structure rather than a change of position in the elements of the aether.

Through various vicissitudes, the idea of an aether has come down to us through the centuries. Even when it was most in disfavour we can see that the replacing hypotheses were suggested by some phase of its supposed action. And the idea has been pregnant with scientific advances. Thus in 1853 Thomson investigated the mathematical theory of the discharge of a condenser showing† the conditions under which the discharge was oscillatory and how to determine the frequency. Maxwell's discussion of the dynamics of the electromagnetic field showed that there was another phase of the problem to be considered, namely, the radiation of electromagnetic energy. In this way he was led to the idea of waves of widely varying frequencies emitted from oscillating systems. In 1888 Heinrich Hertz (1857-1894) was successful in obtaining such waves and in showing that their velocity of propagation was, as Maxwell's theory demanded, the same as that of light.‡ As the years have passed the gamut of electromagnetic waves from gamma rays of length 0.000,000,007 millimetres to wireless waves of lengths exceeding 50 kilometres has been fairly well explored. Between the gamma or Roentgen rays and the ultraviolet rays of the Schumann region there is still a gap of nearly five octaves (0.000,001,2 to 0.000,036 millimetres). Again between the longest radiations from the quartz mercury lamp (0.342 mm.) to the shortest electric waves known (2 mms.) there is a gap of a little over two octaves. Otherwise we have knowledge of waves extending 15 or 16 octaves below and some 26 octaves above the luminous radiations. Many of these radiations are of considerable importance, and there is a little doubt that the call of pure science and the fascination of aether theory have helped materially in their discovery and investigation. Maxwell's theory also proved§ what had been anticipated by Euler,‖ that light should exert a pressure, and this result was confirmed experimentally many years later.¶

* *Phil. Mag.*, xxi. (1861), pp. 161, 281, 338; xxiii. (1862), pp. 12, 85; Maxwell, *Scientific Papers*, i., p. 451.

† *Phil. Mag.* (4) v. (1853), p. 400; Kelvin, *Math. & Phys. Papers*, i., p. 540.

‡ *Ann. d. Phys.*, xxxiv. (1888), p. 551.

§ Maxwell, *Treatise on Electricity and Magnetism*, par. 792.

‖ *Histoire de l'Acad. de Berlin*, ii. (1748), p. 117.

¶ P. Lebedew, *Ann. d. Phys.*, vi. (1901), p. 433. E. F. Nichols and G. F. Hull, *Phys. Rev.*, xiii. (1901), p. 293.

The writer has discussed elsewhere* the results of attempts to solve the problem of the relative motion of matter and the aether. The results have been bewildering. Bradley's aberration discovery of 1728 is most easily explained on the assumption that the earth moves freely through the aether, and Young in 1804 showed that this assumption applies equally as well on a wave theory as on the corpuscular emission theory. Fresnel in 1818 derived a formula for an aether drift, indicating a drag on the aether by matter whose refractive index differed from unity. This formula was supported by experiments in 1852 by Fizeau on light travelling in moving water, and by aberration tests in 1871 by Airy with a telescope filled with water. As Maxwell in his theories treated matter merely as a modification of the aether, distinguished only by altered values of certain constants, we may say that he assumed that matter and aether move together. Michelson and Morley's experiment of 1887 appeared to show a complete drag of the aether by the earth, but Lodge in 1892 could obtain no apparent effect on the aether by the rapid rotation of a massive flywheel. Such discordant results could be reconciled only by some such revolutionary theory as that advanced by Fitzgerald in 1892† or by Einstein in 1905.‡ The difficulties which have arisen in connection with theories of the aether are therefore responsible for giving us one of the greatest contributions to physical science and to philosophy—the theory of relativity. It is therefore good to know that while Einstein set out by ignoring (without affirming or denying) the aether, he finds it useful in later papers to introduce it, though for a novel purpose. All matter is transparent to gravity, although in most cases opaque to light through absorption. Current research is occupied principally with the attempt to explain these anomalies by a scrutiny of the internal structure of the atom and a fine-grained aether possessing some of the properties of matter. The history of the aether is undoubtedly a lesson on the value of interaction between theory and experiment, and of the contribution of pure to applied science.

† *Journ. Roy. Soc. W.A.*, v., p. 89 : Ross, *Einstein's Theory of Relativity*, p. 7.
* Lodge, *Nature*, xlvi. (1892), p. 165.
‡ Einstein, *Ann. d. Phys.*, xvii. (1905), p. 891.

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INDEX.

(To Papers only.)

INDEX TO NEW SPECIES DESCRIBED IN THIS VOLUME.

PUBLICATIONS OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

With Names of Authors and short titles of Papers.

Journals and Proceedings.

VOL. I., 1914–1915.—M. A. Browne—Approximate Summation of Series. W. B. Alexander—A New Stomatopod—Further Notes on Stomatopods—History of Zoology in W.A., Part II.—Birds met by Vlamingh on Swan River. W. J. Dakin—Marine Biology in W.A.—Vitalism in Modern Biology. H. B. Curlewis—Tides. E. S. Simpson—Natrojarosite from Kundip. W. D. Campbell—Natives of Sunday Island. C. Hedley—Preliminary Index of Mollusca of W.A.

VOL. II., 1915–1916.—A. Gibb Maitland—Problems of Western Australian Geology. F. E. Allum—Principles of Currency. J. T. Jutson and E. S. Simpson—Geology and Physiography of Albany. A. Montgomery—Physiographical Characteristics of Western Australia. W. B. Alexander—Orthopterous Insects from W.A.—A New Species of *Evoxymetopon.*

VOL. III., 1916–1917.—W. J. Hancock—X-rays. W. B. Alexander—History of Zoology in W.A., Part III. H. W. B. Talbot & E. de C. Clarke—Expedition to South Australian Border. A. D. Ross—Gyrostatic Action. W. V. Fitzgerald—Botany of Kimberleys.

VOL. IV., 1917–1918.—A. Montgomery—Closer Application of Science to Industries. F. E. Allum—Decimalisation of British Currency. W. B. Alexander—New Species of Marsupial. W. J. Dakin—W. A. Pitcher Plant.

VOL. V., 1918–1919.—W. J. Hancock—Science and Civilisation. W. G. Woolnough—Physiographic Elements of Swan Coastal Plain. J. S. Battye—Causes of Colonisation of W.A. W. Kingsmill—Acclimatisation. W. A. Saw—Town-planning. A. R. L. Wright—Houses in W.A. D. A. Herbert—The W.A. Christmas Tree. A. D. Ross—Light and the Ether. E. S. Simpson—Hisingerite.

VOL. VI., PART I., 1919–1920.—J. L. Somerville—Uplift in Neighbourhood of Perth. W. B. Alexander—W. A. Lampreys—Aboriginal Names of Animals—(With C. E. Lane-Poole and D. A. Herbert) Indigenous Plants of Economic Importance. D. A. Herbert—Climbing of Waterfall by Lampreys—*Xanthorrhoea reflexa.* E. de C. Clarke—Glaciated Boulders near Leonora and Laverton. E. Cheel—New Species of *Daviesia.*

VOL. VI., PART II., 1919–1920.—G. L. Sutton—Science and Agriculture—Absorption of Moisture by Wheat. D. A. Herbert—Confusion between *Acacia cyanophylla, A. seligna* and *A. cyclopis*—Contributions to Flora of W.A. No. 1 *Proteaceae, Rutaceae, Polyporaceae, Phalloideae.* E. S. Simpson—Cobaltiferous Epsomite. S. K. Montgomery—*Hymenosomidae* from Swan River. J. Clark—W.A. Ant-nest Beetles. E. Ashby—Three Species of *Stenochiton* from W.A.

VOL. VII., 1920–1921.—E. S. Simpson—Science and Mineral Industry—Staurolite from Mogumber. L. Glauert—W.A. Petrels and Albatrosses—Fish Collected near Albany—Pleistocene Fossil Vertebrates from Fitzroy River—Teeth of *Nototherium Mitchelli.* M. Aurousseau and E. A. Budge—Terraces of Swan and Helena Rivers. H. Bowley—Chemistry of Alunite. D. A. Herbert—Contributions to Flora of W.A., Nos. 2 and 3—Parasitism of the Quandong—Parasitism of the Sandalwood—*Xanthorrhoea* in W.A. G. E. Nicholls—*Dero roseola* (Naidiform Worm). W. E. Shelton—Xerophytism in Swan River District.

Vol. VIII., 1921–1922.—F. E. Allum—Modern Currency Problems. G. L. Sutton—Pedigree Selection of Wheat. L. Glauert—Contributions to Fauna of W.A., No. 1. E. Ashby—*Acanthopleura.* D. A. Herbert—Contributions to Flora of W.A., No. 4. A. Cayzer and F. W. Wakefield—*Darwinia pimelioides.* R. D. Thompson—Solar Eclipse of September 21, 1922.

Vol. IX., Part I., 1922–1923. R. A. Farquharson—Impsonite in W.A.—Geology of Kalgoorlie. C. A. Gardner—Contributions to Flora of W.A., Nos. 1 and 2. J. Clark—New Myrmecophilous Beetle—Honey Ants. L. Glauert—Cretaceous Echinid—Contributions to Flora of W.A., Nos. 2 and 3. R. J. Tillyard—Embioptera of W.A.

Vol. IX., Part II., 1923.—E. de C. Clarke—Pre-Cambrian in W.A. R. Trumpler—Structure of Sidereal Universe. E. S. Simpson—Secondary Sulphates and Chert in Nullagine Series. T. H. Withers—Cretaceous Cirripede. A. D. Ross and R. D. Thompson—Energy involved in recent Outburst of Beta Ceti. E. O. G. Shann—Foreign Exchange. J. Clark—Australian Formicidae. C. A. Gardner—Contributions to Flora of W.A., No. 3. L. W. Phillips—Essential Oils of some W.A. Plants.

Vol. X., 1923–1924.—W. H. Shields—Sand Bars. E. Cheel—New Myrtaceous Plant. L. Glauert—Fossil Plants from Mingenew and Irwin River—*Phreatoicus Palustris*—Contributions to Fauna of W.A., No. 5. E. Ashby—New Species of *Acanthochiton.* A. D. Ross—Einstein Eclipse Tests—Theories Regarding the Æether. G. E. Nicholls and D. F. Milner—*Hyperoedesipus Plumosus.* G. E. Nicholls—*Phreatoicus Lintoni*—*Neoniphargus Branchialis.* W. E. Wood—Increase of Salt in Soil and Streams. E. S. Simpson—Goongarrite. W. M. Carne and E. J. Limbourn—Natural Cross-breds in Oats and Barley. J. Clark—Australian Formicidae. C. A. Gardner—The So-called *Ericopsis Formosus.*

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